Infinite Energy™
Cold Fusion and New Energy Technology
Volume 4, Issue 21 • 1998

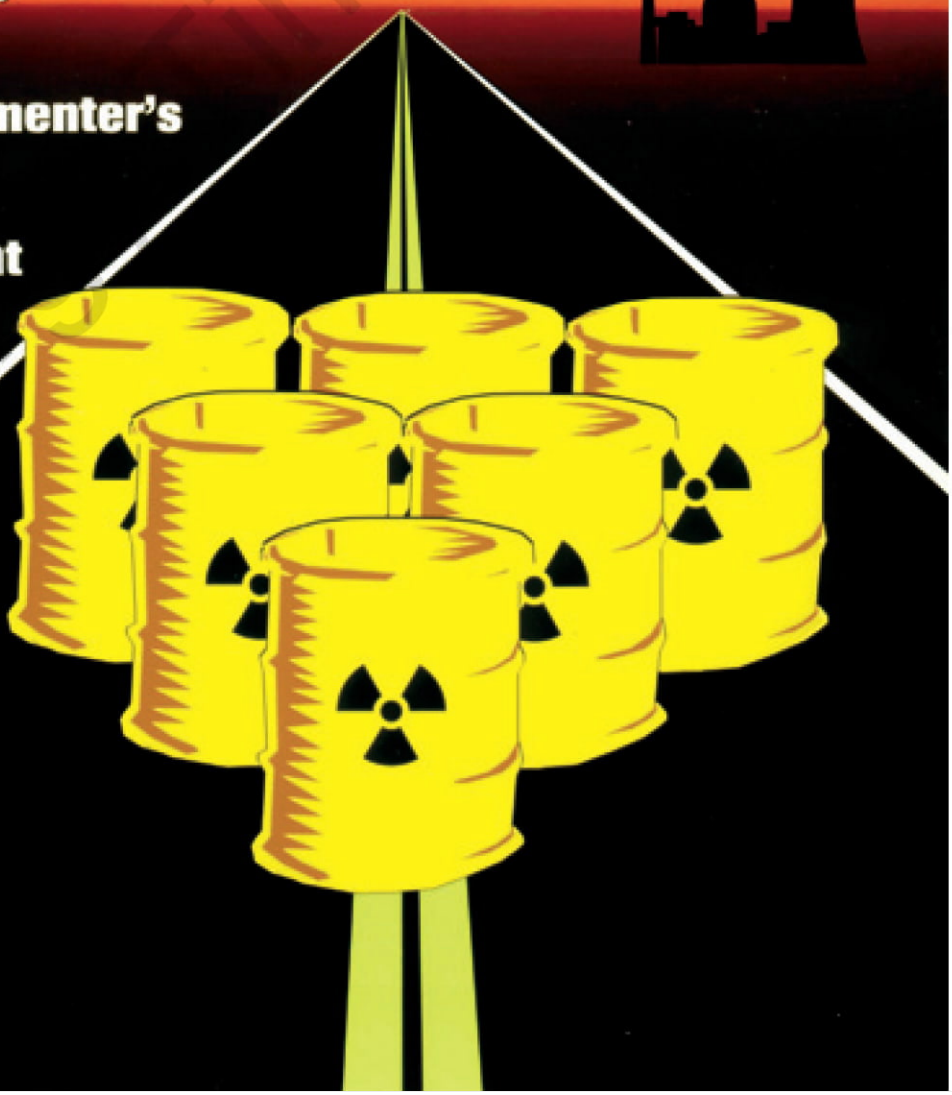
End of the Road for Radioactive Waste?

Photoremediation Shows Promise as Emerging Solution

Paul M. Brown, Ph.D.
Nuclear Solutions, LLC
President

Physicist Robert Parmenter's Cold Fusion Theory Finally Published – Despite Establishment Opposition

POWER SURGE: Guide to the Coming Energy Revolution Reviewed



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Dr. Eugene Mallove (*Infinite Energy* Magazine)
Cold Fusion and New Energy: Science, Technology, and Business

Dr. Peter Graneau (Centre for Electromagnetics Research)
Lightning Generates MHD Power; The Cause of Thunder

Dr. Edmund Storms (Los Alamos National Laboratory, Retired)
Chemically Assisted Nuclear Reactions

Dr. Paulo Correa (Labofex, Toronto, Canada):
Pulsed Abnormal Glow Discharge Reactor: An Update

Dr. Daniel Cavicchio (New Energy Partners)
Investing in New Energy Technologies

Jed Rothwell (*Infinite Energy* Magazine)
Cold Fusion Technology: Comparisons from the History of Technology

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by Tadahiko Mizuno
Nuclear Engineering, Hokkaido University

ENGLISH TRANSLATION
by Jed Rothwell

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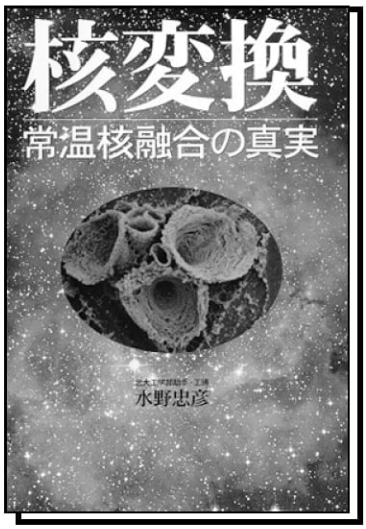

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Cold Fusion and New Energy Technology

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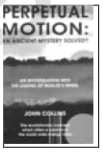

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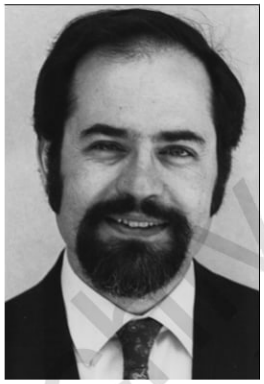
By Eugene F. Mallove, Sc.D.

The Passage of Time ...



Here in New Hampshire the late August leaves give ever-so-slight notice of the approaching fall, when red and yellow and orange will blanket tranquil hills with a riot of color. Soon visitors from near and far will arrive to attend the 1998 Cold Fusion and New Energy Symposium in Manchester, which we and Nature have conveniently arranged to coincide with the peak of the foliage season. One wonders whether the leaves, like the bacteria and higher life forms in some experiments that others have reported, have been transmuting elements all summer long.

Leaves are like lives—emerging, growing, and falling. The unfolding of history in the brief windows of our lives in Cosmic Time makes us aware of the importance of time. So much to do, so little time within which to do it. But we try our best. There are so many questions to be answered, so many extraordinary claims to be properly investigated, and so many people who should be informed of these new directions—and not enough time.

We are blessed with lots of people who have helped our cause. We keep trying to multiply them. A new-found journalist investigator, Charles Platt, will have his major article on cold fusion published in the November *Wired* magazine, on the newsstands in late October. Watch for it. Had we not invited him to explore our field and visit laboratories and ICCF-7, this information would not have reached the prospective 700,000 audience of high-tech and high-gloss *Wired*. It has taken time to get to this audience of enlightened technologists, *lots* of care and time.

Almost a year ago, this magazine lost one of the leading lights of our field with the death of engineer/author Chris Tinsley. We deeply feel the passage of that time. A year later, our Publishing Office has expanded and hums with the enthusiastic efforts of a growing staff. Newly arrived here in Bow, New Hampshire is Mr. Ed Wall, who joins us as a key New Energy Research Laboratory engineer—charged with helping your dear Editor and others check out various claims for anomalous engines and processes. Burdened as we are already with testing tasks too awesome to contemplate all at once, it is a blessing that Ed made the decision to arrive here when he did! Expect greater things from now on... And remember, if you are impatient for results and answers: *Things take time.*

Our cover story concerns not *new* nuclear physics, but *overlooked* applications of the *old* nuclear physics—what an overlooked application! Dr. Paul Brown, a respected physicist with Nuclear Solutions, LLC in Colorado, has proposed (and proved, he says) that gamma ray stimulation of hazardous nuclear waste can dramatically cut the half-lives of most of the radioactive nuclides of current focus. Furthermore, the neutron emission from such resonant excitation of nuclei can provide a source of power to carry out the process. We understand that high level discussions with several major corporations may lead to this patent-pending process being introduced in the relatively near term.

Dr. Brown sent me a personal communication that highlights this historical development:

"As you probably know, we are using a high energy x-ray machine which allows us to run experiments on the process ourselves. The latest material I have found in the literature was the work done at Los Alamos where they used colliding electron-positron beams to generate 14 MeV photons, which were then used to photo-disintegrate cesium-137 to cesium-136. The purpose of the experiment was to measure the binding energy of the neutron.

"This brings up a very interesting progression. Photo-disintegration was first discovered by using natural gamma emission exposed to deuterium, which emits a neutron to become a hydrogen nucleus. This experiment was further refined to determine the mass of the ejected neutron. Then, it was discovered that the same process (photo-disintegration) could be applied to beryllium-9 which emits a neutron to become Be-8, which almost immediately decays into two helium nuclei (alpha particles). This is where work stopped for some time, because this was all done using natural gamma emission from various radioisotopes. But then came the betatron in 1940. This allowed the generation of high-energy electrons which were then converted to x-rays in the usual manner, allowing the 'mapping' of the nucleon binding energies for all the elements. Of course, all this data is tabulated in the nuclear cross-sections reference. Then, in summary, the gamma-neutron reaction (photo-disintegration) has been used for many years as a research tool for determining the mass of the neutron and its binding energy to the nucleus.

"The gamma-neutron reaction has also seen practical application, namely the production of neutrons. For many years now, when a source of neutrons is required for a particular application, photo-disintegration, usually of Be-9, is used to generate these neutrons. The number of published papers using this technology over the years is far too great to list.

"I find it interesting that research scientists have been utilizing this principle repeatedly, and in their zeal to develop ever-increasing, high-energy, accelerators and collisions, they simply overlooked the obvious."

Dr. Brown is describing paradigm paralysis perfectly. This is related to the kind of paralysis and lack of vision that has prevented cold fusion and low energy nuclear reactions from receiving the considerable attention that they deserve in the wider scientific community. The hot fusion paradigm has been blind to the new.

Dr. Brown continues his discussion of the implications of photo-disintegration: "Of course, the neutrons produced may also be used in a beneficial manner, kind of a nice by-product. Additionally, I must point out that the treated isotope, with its much shorter half-life is a heat source. This heat may be used together with off-the-shelf technology to generate electricity. In scientific terms: a drum of cesium-137 takes one day to treat. This drum becomes a heat source for the next ten months, and this one drum will produce enough heat to power the x-ray machine for that 10 month period, through the use of a standard heat-to-electricity generator. The real key to this is the odd-A nuclei. In these unstable, radioactive atoms, the neutron is loosely bound. By putting in just a small amount of energy, we unleash the unstable energy contained therein. Much the same as putting

Editorial continued on page 5

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Editorial continued from page 3

a match to a log."

Wonderful! This "conventional" process bares some similarity to the match-to-the-log analogy that we have used with "heat-after-death" phenomena that have been found in cold fusion reactions. Once started, the excess heat continues even though the input power has been removed. Cold fusion is really a new kind of "nuclear fire"—without the negative environmental consequences of an uncontrolled fission industry. But now, Nuclear Solutions, LLC has come up with a way of giving us more energy options.

Though Dr. Brown's technology of "photoremediation" of nuclear waste is very welcome, we are mindful of the more astonishing heretical remediation technologies—the electrochemical transmutation methods under development by CETI, The Cincinnati Group, Trenergy, and others soon to come into the fold. It could well be that all these technologies will play a symbiotic role in cleaning up the radioactive waste problem that the nuclear age has left us. Dr. Brown will be at the October 11th CF/NE Symposium in Manchester to discuss progress in his research, as well as to revisit his patented nuclear battery technology that was briefly touched upon in a past issue of *Infinite Energy* #13/14, p. 52.

We are very proud to be able to publish in this issue the theoretical work of Dr. Robert H. Parmenter, Professor Emeritus of Physics from the University of Arizona. His paper, "A Possible Scenario for the Onset of Cold Fusion in Deuterated Metals," had been rejected out of hand four years ago by a mainstream physics journal because, it was said by a reviewer: "cold fusion does not exist." This rejection occurred even after Parmenter's co-authoring, with physics Nobel Laureate Willis E. Lamb, Jr., of three cold fusion theoretical articles in the *Proceedings of the National Academy of Sciences*. The abstracts of the latter articles are reproduced in this issue.

Dr. Edmund Storms, productive as ever in his retirement from Los Alamos National Laboratory, graces this issue with another of his extensive reviews of the cold fusion field. Incidentally, but pertinently, "Cold Fusion Revisited" (pp. 16-29) was rejected by the *International Journal of Modern Physics* for the usual spurious reasons.

Does this pattern of rejections of quality papers on cold fusion tell you anything about the health of modern physics? If the establishment physics journals are sick with pathological skepticism (Ed's phrase) toward cold fusion, then we at *Infinite Energy* are quite happy to make up for its grotesque, unconscionable failings.

Editorial continues on page 37

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LETTERS TO THE EDITOR

To the Editor:

Regarding the article in [Issue 20, p. 38—Ed.] *Infinite Energy*, I concur entirely with the sentiments expressed by Barry Merriman (though only largely with those of Francis Bacon) about Joseph Champion. Joe Champion turned out to be a flawed character. His enthusiasm for his alleged discoveries led him to make absurd exaggerations[1] and to tell (self-aggrandizing) lies. Thus, for those who were observers of these characteristics, his scientific statements lost credibility.

However, and hence the note, it must not be forgotten that when in 1992 Joe Champion asked me, at Texas A&M University, to direct a group to make an independent examination of his claims to have demonstrated metal-to-metal transmutation experiments in a Mexican University, the subject was a joke.[2] Now, six years later, transmutation is evidenced in dozens of papers, (originating) in many countries, and is a topic of day long sessions at the American Nuclear Society meetings.

Moreover, Champion (equipped only with a certificate in electronics) gave us two *ideas*, the first of which was accompanied by a proposal containing calculations which I thought to be rational. Essentially, he sought nuclei with quadrupole moments and proposed to subject compounds containing them, dissolved in solution, to radiation (under a magnetic field) at a frequency which would overlap those in the nucleus (not unakin to n.m.r.). Several years after Champion's (unpublished) proposal, a completely independent suggestion was published by the Russian physicist Kucherov to the effect that the phonon spectra of palladium hydride would overlap those of the quadrupoles in certain nuclei - and build up energy until it reached fission causing values. (Kucherov's suggestions were accompanied by *an outline* of his calculations; I recall they included attention to the competing deactivation velocity which I don't recall in Champion's.)

Champion's second suggestion was not accompanied by a written rationalization but by his notebook from experiments done at the Mexican Laboratory which seemed to show transmutation occurring as a result of detonation. Corresponding to this, Filimonov and Kobets, reporting in ICCF-7 1998, say that they have found that explosive detonations reduce the activity of ^{137}Cs 50-100%.

So when, as I expect, the day comes when Fleischmann and Pons are called to Stockholm, I would hope the Swedish Committee at least gives Champion a place at the banquet, and on his name tag should stand the words "Joe Champion - convicted felon - explorer."[3]

John O'M. Bockris
Distinguished Professor of Chemistry (Retired)
Texas A&M University

[1]In fact, I suggested to Champion that he be likened to that redoubtable German knight, Baron von Münchhausen, who, when challenged as to his strength, told the other knights he could, indeed, lift himself by his own shoe-laces.

[2]My reason for accepting the challenge was that we had had at this time plenty of evidence for tritium from deuterium (equally impossible according to the 1992 paradigm in Physics).

[3]Champion claimed to have electrolyzed a solution before 1989 and "produced a radioactive gas," observing excess heat. I met a physicist who said he had detected the radioactivity. Two of my coworkers, in 1990, measured excess heat for a brief period in a Champion set-up in a lab then managed by Champion.

•—•—•

Dear Dr. Mallove:

I would like to say that I found issue No. 17 of *Infinite Energy* more fascinating than usual. Of particular interest to me was the article titled, "The Possible Source of Energy for Anomalous Effects Reported in *Infinite Energy*" by Dr. Paul E. Rowe. Dr. Rowe presented his theory of hydrogen production from the vacuum convincingly. However, I do not accept his interpretation that the vacuum is composed of a Bose-Einstein condensed proton electron matrix. If one were to assume the existence of such a proton electron matrix vacuum, then it should be explained why it is normal matter and not anti-matter. There is good theoretical evidence to support the idea that a matter anti-matter symmetry exists in our universe which undoubtedly would be true if the universe was created from quantum particle pair fluctuations. All the anti-matter might simply be in another place. But there should be no reason for a highly condensed proton electron matrix to be pervading all space.

Dr. Rowe gives many good examples of apparatuses that are capable of this mysterious manifestation of hydrogen. I do not dispute that hydrogen was created, only the idea that its origins were in a proton electron matrix. I feel that the most probable explanation is nuclear reactions. For example, the hydrogen produced from electrical discharges in helium might come from the fusion of trace amounts of helium three:

$$^{3}He + {}^{3}He \rightarrow {}^{4}He + 2\ {}^{1}H$$

The presence of hydrogen found in reactions involving aluminum might be due to the following reaction:

$$^{27}Al + {}^{16}O \rightarrow {}^{39}K + {}^{4}He \quad Q=8.73\ MeV$$

The helium nuclei produced could have enough kinetic energy to transmute trace amounts of nitrogen (remaining in the vacuum after it has been evacuated) into hydrogen and oxygen.

$$^{14}N + {}^{4}He \rightarrow {}^{17}O + {}^{1}H$$

The hydrogen found in experiments involving carbon dioxide might be explained by the following reaction

$$^{13}C + {}^{16}O + {}^{16}O \rightarrow {}^{41}Ca + {}^{4}He$$
$$Q=26.36\ MeV$$

Here again, the helium nuclei produced can have enough energy to produce hydrogen from the transmutation of trace amounts of nitrogen. More experiments need to be done to hunt for the other elements produced by these transmutations.

If it is found that the hydrogen is not due to nuclear reactions, then we can

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always turn to the vacuum for an explanation. Not a proton electron matrix model, but the quantum particle pair fluctuations. It might be that some mechanism exists that with sufficient conditions will allow some of the proton pairs and electron pairs to remain in existence and form hydrogen and anti-hydrogen. The anti-hydrogen would then annihilate with other matter, such as the wall of the vacuum chamber, leaving an overall net gain in the amount of normal hydrogen present. I think more experiments should be done to search for other transmutation products and possible gamma rays.

Scott A. Thaller
Wexford, PA

•—•—•

Dear Dr. Mallove:

Enclosed is my check in the amount of $29.95 to renew the subscription of *Infinite Energy* magazine for my husband, Renato DiIulio, which I believe expires after Issue #20 (forthcoming).

We have been fascinated and inspired to read of so many new developments in technology, particularly with the promise of remediating pollution, radiation, and so many other critical matters affecting the environmental conditions of the planet.

The ECA technology and AquaFuel are exciting, and we look forward to receiving further information about application of these technologies, while realizing that it may take precious time to see them implemented into common use.

We do not have technical backgrounds, but your articles, while providing essential detailed technical information, are written so that the "layman" may at least comprehend the basic concepts. It is exciting to be on the "cutting edge" of these breakthrough developments.

Thank you so much for your work in bringing this information to the public at large, and for providing a place for those working in these new arenas to come together to network and encourage one another.

Patricia DiIulio
San Pablo, CA

•—•—•

Herewith, my two-year renewal. I became half-way convinced that I ought to be a skeptic when Dr. Randall Mills gave up on his liquid/potassium hydroxide operations, but what the hell? I'll give it another chance.

W. Brown
Katy, TX

•—•—•

Hello, my name is George I'm 14 and I was writing to say that cold fusion could be the most important discovery of the 20th and maybe the 21st century. I was wondering why our government is rejecting it. I know that when it comes to be there would be no work for people who work in nuclear/all electricity companies but would also open more research and other jobs, not to mention eliminate pollution and the cost of electricity. And also I know if I had millions of dollars I would give some for the cause, so try Bill Gates.

Well thank you for your time, I know I'm young but I love science and physics. And I would love for someone to write me back with some information.

Your friend, George

•—•—•

July 27, 1998

Dear Dr. Mallove,

Monsanto Enviro-Chem Systems, Inc., grants *Infinite Energy* magazine the authority to publish the enclosed letter in its entirety only.

No authority is granted to publish the enclosed letter in any edited form.

Sincerely,
Robyn Bartosch
New Business Development
Monsanto Enviro-Chem Systems
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Dear Dr. Mallove,

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Sincerely,
Robyn Bartosch
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Dr. Mallove's Response to the Monsanto Enviro-Chem Systems Letter:

We are very happy to print the above letter from Mr. Robyn Bartosch of Monsanto Enviro-Chem Systems. Readers of *Infinite Energy* should know that my decision, under deadline pressure, to print the full ECA brochure in Issue #18

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was motivated by our desire to have the *most accurate* portrayal of the Monsanto position—as given in its lavish brochure. If we had only printed extensive excerpts, we could have stayed fully within the letter of the law concerning copyright, but this would not have given a complete picture.

Now it seems that Monsanto is backtracking on its claims about ECA. This is most unfortunate, because we believe through our checks with independent sources—that this Monsanto letter is *highly misleading*. Note the very weak statement in the letter: "...pending further evaluation of ECA technology, MEC has withdrawn literature publicizing any characterization of ECA." That is perfect bureaucratese for "no comment at this time."

In point of fact, the ECA process appears to be even more spectacular than we at *IE* had originally believed. For example, we have gained independent knowledge of full verification of medical/biological effects from the process at a well-known U.S. testing laboratory noted for its impartial studies. We cannot now name this laboratory because its work was described to us "off the record" by a concerned intermediary. And, we have confirmed that other corporate activity beyond that of Monsanto's certainly does exist for this technology.

Further, we have learned that Japanese use of the technology in hospitals has achieved remarkable results, some of which have been documented on publicly broadcast television programs that we have viewed. It also appears that activities are underway in the U.S. to develop the technology for defense against biological warfare agents. This work is presently classified, but we have confirmed its existence through an independent source.

For Monsanto Enviro-Chem Systems to attempt to obfuscate the important scientific, technological, and perhaps national security issues implicit in this technology is tragic and indefensible. We have no idea what motivates this kind of misinformation, but we can assure our readers that it will not work. Within 6 to 9 months we be able to provide *Infinite Energy* readers with detailed information that will allow them to judge for themselves the reality of ECA, independent of the bewildering position of Monsanto as stated in Mr. Bartosch's unfortunate letter.

Eugene F. Mallove, Sc.D.
Editor-in-Chief

•—•—•

The following are comments from our online guest book and www information site.
http:/ / www.infinite-energy.com

"Continue your tests. We are desperate for energy devices here in the arctic because of village isolation and the difficulty of obtaining fuel, but they must be dependable and damned near indestructible."
Bruce Ingersoll

"Add formulas for novices like me to mess around with... I can see a day when cold fusion is coupled with superconductivity to produce not only clean, long-lasting energy but efficient energy... While at college, we had a grant from NASA (NAG 5-1267) to see if wireless power was feasible. We took many theories from Nikola Tesla's work. With some HP spectrum analyzers we got from NASA, we were able to prove and disprove some of them." Paul Ross

"We have a patron that is interested and he enjoys reading your magazine...The school children in the area are researching energy and alternate energy. This is a good resource for the college-age and high school-age patrons. Thanks."
Peggy Stokes, Periodicals Librarian

∞

Corrections from Issue #20

Additional Contact Information (and correction) **for Harold Josephs.**

Author of ***Rhodium-Catalyzed Fusion in Palladium*, pg. 47, Issue #20.**

Harold C. Josephs
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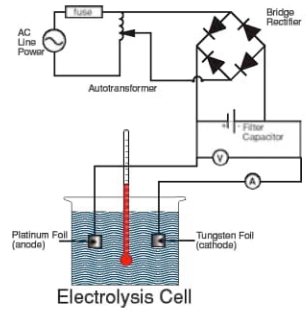
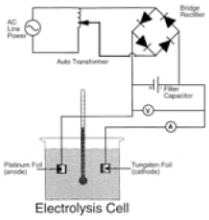
Guadalupita, NM 87722
Ph: 505-387-6696



Corrected schematic (above) of Electrical Circuit Used in our Ohmori-Mizuno experiment. (Artwork: Jeremy Slayton)



From Issue #20 pg. 11

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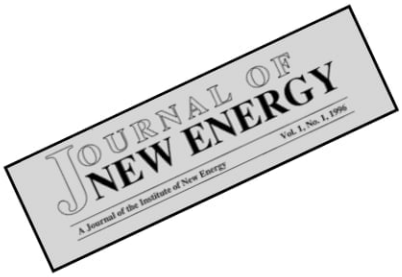

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NEUTRALIZING NUCLEAR WASTE USING APPLIED PHYSICS

Paul M. Brown, Ph.D.

NUCLEAR SOLUTIONS, LLC.
20100 E. 32nd Avenue Parkway, Suite 185, Aurora, CO 80011
Ph: (303) 574-9697; Fax: (303) 574-9699; www.nucsol.com

Introduction

Nuclear Solutions LLC has developed a process for neutralizing radioactive waste products whereby gamma radiation (x-rays) is used to induce nuclear transformations that change the normal half-life of radioisotopes, usually measured in thousands of years to a half-life measured in days, simply by using applied nuclear physics. This means that the radioactive waste products decay into non-radioactive stable elements in a matter of days. Patents are now pending.

Nuclear Waste (Fission Products)

The two fission products of principal concern because of their substantial thermal impact on the repository as opposed to posing a health risk are Sr^{90} and Cs^{137}. These two radionuclides are dominant contributors to the heat released by spent fuel at least for the first several decades. Cs^{137} is also a major source of penetrating radiation emitted by spent fuel. The two fission products of principal concern because of their potential contribution to health risk are Tc^{99} and I^{129}. They are of principal concern because they are long-lived, produced in significant amounts in the fission process, generally soluble under geologic conditions, and migrate relatively quickly under common ground water conditions.

The long-term toxicity of spent fuel is dominated by the actinides such as Np^{237}, $U^{234,236}$ and $Pu^{239,240,242}$. However, the long-term risk is dominated in most scenarios by I^{129} and Tc^{99} because they are typically soluble and mobile in ground water pathways. By being relatively insoluble under most conditions, the actinides are not mobile, so despite their high toxicity they contribute very little to the long-term exposure risk in scenarios where ground water transport is important.[1]

Nuclear Physics

The nuclear charge is equal to +Ze, where Z is a whole number called the atomic number of the atom. The nuclear charge arises from the presence of Z protons in the nucleus. Atoms and nuclei are named according to their Z-values. For hydrogen, Z=1; for helium, Z=2; and so on. The mass number A is equal to the total number of particles, of protons and neutrons (collectively called nucleons), in the nucleus. Of the A nucleons in the nucleus, Z are protons and the rest, N=A-Z, are neutrons. N is called the neutron number.

David Samuel - President of Nuclear Solutions (right), congratulates Dr. Brown after successful transmutation of cesium.

In much of physics and practically the whole of chemistry, Z is far more significant than A (or N). This is because most of the ordinary properties of matter are due to the clouds of electrons outside the nuclei. In nuclear science, on the other hand, the situation is entirely different. A ranks equal in importance with Z, and its value must be added to the chemical symbol.

Just as nuclides having the same Z-value are classified together as isotopes, as are those with the same A-values (but different Z-values) classified together as *isobars*, and those with the same N-values as *isotones*. Thus Ar^{40} and Ca^{40} are isobars, and Si^{30}, P^{31} and S^{32} are isotones (with N=16). Particles such as electrons and nucleons which obey the Pauli exclusion principle are called fermions and are said to follow Fermi-Dirac statistics. Those not so limited are called bosons and are said to follow Bose-Einstein statistics. Even-A nuclei are bosons and odd-A nuclei are fermions.

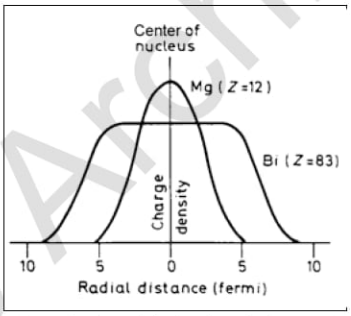

Figure 1. The distribution of charge in a small and large nucleus. In the latter there is a central core of constant density and a diffuse outer region.

All attempts to form a picture of the nucleus today are based on the idea that it is composed of protons and neutrons (Figure 1). The nucleus is much smaller than the atom. Roughly, the ratio of their diameters is as $1:10^4$. The actual size is given sufficiently well by the formula $R=1.4A^{1/3}$, where R is the radius in fermis (10^{-13} cm). All nuclei have the same average density, however large they may be. In SI units the density has the enormous value of 2×10^{17} kg/cm^3.

Nuclei have a dense central core, which is nearly homogenous, surrounded by an outer layer in which the density tapers to zero. The outer layer is about 2.4 fermis thick.

Radioactive Decay

In radioactive decay, nuclei change spontaneously in the direction of greater stability, losing energy in the process.

Types of Radioactive Decay:

1. α-decay, in which the nucleus emits an alpha particle, *e.g.*, $U^{238} \rightarrow Th^{234} + He^4$.
2. β^--decay, in which the nucleus emits an electron, *e.g*, $P^{32} \rightarrow S^{32} + \beta^-$. An electron emitted from the nucleus is known as a beta particle.
3. β^+-decay, in which the nucleus emits a positron, *e.g.*, $F^{18} \rightarrow O^{18} + \beta^+$.
4. EC-decay (electron capture decay), in which the nucleus captures an electron from the electron cloud of the atom, *e.g.*, $Mn^{54} + e^- \rightarrow Cr^{54}$.
5. ITs (isomeric transitions), in which the nucleus undergoes a transition from an upper to a lower energy state, *e.g.*, $Br^{80} \rightarrow Br^{80} + \gamma$.
6. SF (spontaneous fission), in which the nucleus divides into two roughly equal parts (fission fragments) plus about two neutrons, *e.g.*, Cf^{254}.

β^-, β^+, and EC decay are often grouped together under the general heading of beta decay.

Each radioactive species undergoes decay at a characteristic rate, in the sense that a certain proportion of the nuclei in a large assemblage decay in a given time interval. If there are N atoms,

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the rate is $-dN/dt$, and this is proportional to N, such that $dN/dt = -\lambda N$. The constant λ is known as the disintegration constant. A convenient indication of the decay rate is the half-life T, which is the period of time during which one-half of the nuclei in a large assembly decay. T is related to λ by the equation $\lambda T = \ln 2 = 0.693$.

A *stability line* may be drawn through the middle of the band of stable nuclides and is represented by the following equation, $N-Z = ZA^{2/3}/60$. No odd-Z element has more than two stable isotopes, whereas even-Z elements can have any number up to 10. An odd-A element may be either even Z, odd N or odd Z and even N. In odd-A nuclei, there is one unpaired nucleon. Many of the properties of odd-A nuclei are believed to stem from the single unpaired nucleon.

Nuclear Modeling

Throughout the central region of the nucleus a nucleon experiences on average little change in the forces to which the other nucleons subject it, but towards the boundaries it experiences a net attractive force pulling it back towards the center. The same thing would happen if the nucleon moved inside a potential energy well, the potential energy being constant at the center of the well and rising at the walls (Figure 2).

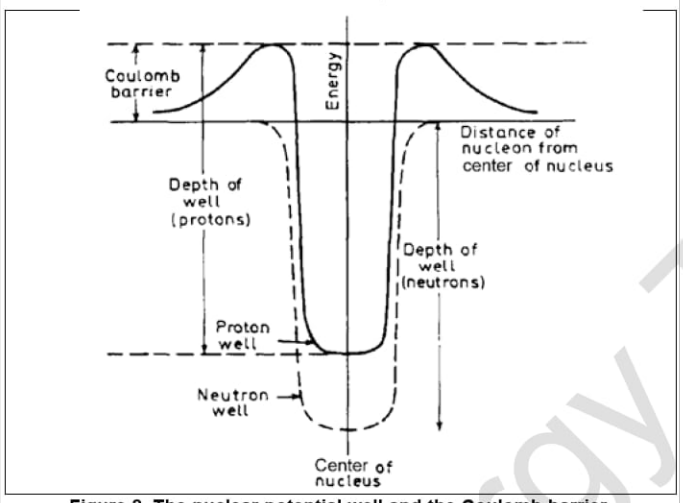

Figure 2. The nuclear potential well and the Coulomb barrier.

For some purposes it is possible to assume that the nucleus can be represented by such a well, and it turns out that a well about 40 MeV deep and of about the same diameter as the nucleus itself has suitable properties.

For protons the well is surrounded by a rim. This is because a proton approaching the nucleus is repelled electrostatically, until the moment when it actually touches the nuclear surface. Once it makes contact, it is attracted and falls into the well. The rim is known as the Coulomb barrier. Its height is given by the energy required to bring the proton up to the nuclear surface, *i.e.*, by Ze^2/R (e= electronic charge, R= nuclear radius). For heavy nuclei such as uranium the barrier is about 10 MeV high. In the general case of an ion of charge +ze and radius r incident on the nucleus the height of the barrier is $Zze^2/(R+r)$.

The concept of the nuclear potential well can be applied both to particles entering or leaving the nucleus, as they do in nuclear reactions, and to nucleons inside the nucleus.

Consideration of the movement of nucleons inside the potential well leads to the shell model of the nucleus. It is assumed that the nucleons move independently inside the well and that their movements are quantized like those of the electrons in the atom. It proves remarkedly successful in accounting for properties of individual nuclei, in both their ground state and excited states. It is particularly successful with odd-A nuclides, in which there is a single unpaired nucleon.

The core excitation model of the nucleus is a model involving electromagnetic properties of the nucleus or the weak-coupling model. This is a model devised for the description of low lying states of odd-A nuclei, which tries to relate such properties to those of the odd particle and the even-even core. In other words, a state of an odd-A nucleus with an angular momentum J is written as

$$\psi(J) = \Sigma A_{Jcj}\phi(J_c, j; J)$$

Here $\phi(J_c, j; J)$ is a state in which the core carries an angular momentum J_c and the odd particle is in the state j.

It is important to note that, formulated in this way, there is no assumption about the *mechanism* which leads to the various core-states. These could be collective vibrations, or single particle excitations, or quasiparticle excitations, or anything else. The essential ingredient that goes into this model is the assumption of a weak coupling between the odd particle and the rest of the nucleus. Weak, that is, in comparison with the interactions involved in the core itself.

Nuclear Reactions (Transmutations Through Radiochemistry)

When neutrons, protons, γ-rays and other kinds of nuclear projectiles impinge on atomic nuclei, they may initiate processes of nuclear change. Such processes are called nuclear reactions. The reactions of γ-rays, known as photodisintegrations, are restricted largely to scattering and the emission of single nucleons, *i.e.*, (γ, γ), (γ, n) and (γ, p) reactions, owing to the limitations on the energies available. For the common low-energy reactions, the changes in Z and A for the target nucleus are as follows (Figure 3):

	$A-3$	$A-2$	$A-1$	A	$A+1$	$A+2$	$A+3$
$Z+2$						α, 2n	α, n
$Z+1$				p, n d, 2n	p, γ d, n		α, p
Z			n, 2n γ, n	n, n p, p etc.	n, γ d, p		
$Z-1$	p, α	d, α	γ, p	n, p			
$Z-2$	n, α						

Figure 3. The emission of single nucleons in (γ, n) and (γ, p) reactions requires an excitation energy of about 8 MeV. In this region the levels overlap and an exact energy match is not needed for absorption of the γ-ray.

In a (γ, n) reaction neither the γ-ray nor the neutron has a Coulomb barrier to surmount, so reaction sets in sharply as soon as the threshold energy is reached. Beyond the maximum, competition from the $(\gamma, 2n)$, $(\gamma, 3n)$, etc., reactions becomes important; the total cross-section for all the (γ, xn) reactions falls to a few millibarns.

Over and above its binding energy in its lowest energy state (the ground state), a nucleus can acquire excitation energy. Like the atomic excitation energy absorbed by the electron clouds and familiar from the Bohr model of the atom, this energy can only be acquired in discrete amounts. The nucleus indeed, like the atom, can exist in a series of excited states, and it can undergo transitions from upper to lower energy levels emitting the surplus energy in the form of electromagnetic radiation. The energy quanta emitted are of relatively high energy; the radiation is thus of very short wavelength, as short as that of X-rays, or shorter. It is called γ-radiation.

The energy levels of a nucleus, and the transitions between them, are often represented by a level diagram such as in Figure 4, for Mg^{26}:

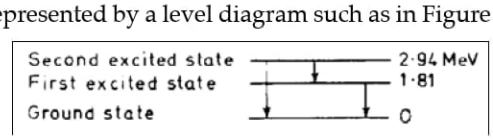

Figure 4. Level diagram.

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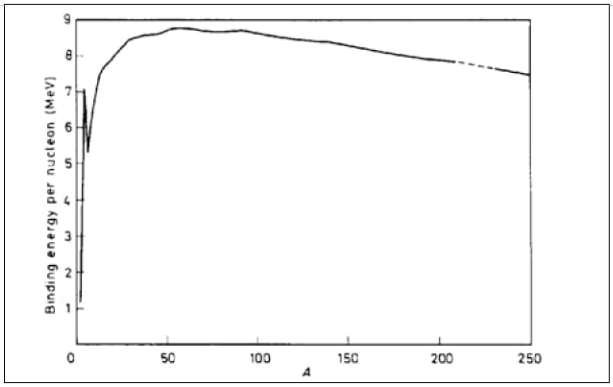

Figure 5. Smoothed binding energy curve for stable nuclei. Binding energy per nucleon as a function of A.

Aside from the lightest nuclei, nuclear binding energies are roughly proportional to nuclear masses (Figure 5). It is therefore convenient to consider the binding energy per nucleon.[2] It is rather important to note that radioactive nuclei tend to have lower binding energies per nucleon than stable nuclei.

The first nuclear reaction induced by photons was discovered by Chadwick and Goldhaber in 1934[3]: the photodisintegration of the deuteron. They used the high energy γ's from a radiothorium source and were able to deduce a fairly accurate value for the neutron mass from their measurement of the energy of the protons produced. The only nuclide other than deuterium with low enough threshold (neutron-binding energy) to permit photodisintegration by naturally occurring gamma rays is Be^9.

Giant Resonance

Reactions between nuclei and low- and medium-energy photons are dominated by what is known as a giant resonance: in all nuclei the excitation function for photon absorption (not just for a specific reaction) goes through a broad maximum a few million electron volts wide. The energy of the resonance peak varies smoothly with A, decreasing from about 24 MeV at O^{16} to about 13 MeV at Bi^{209}. Peak cross sections are 100-300 mb.

This giant-resonance absorption is ascribed to the excitation of dipole vibrations of all the protons against all the neutrons in the nucleus,[4] the protons and neutrons separately behaving as compressible fluids. This model makes some fairly simple predictions about the magnitude and A-dependence of the resonance that are quite well borne out by the experimental data: the integrated cross sections under the resonance peaks are given to good approximation by 0.06NZ/A MeV b, and the peak energies can be approximately represented by $aA^{-1/3}$.[5]

The energy of the dipole resonance is so low that mostly rather simple processes, such as (γ, n), (γ, p), (γ, 2*n*), and photofission reactions, take place in the giant-resonance region (Figure 6). The competition between these processes is governed by the usual statistical considerations of compound-nucleus de-excitation, so that neutron emission usually dominates.

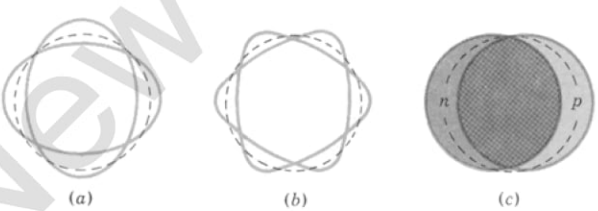

Figure 6. Different types of nuclear vibrations. The two extremes of the vibration are shown by solid curves, and the midpoint of the vibration, a spherical shape, is shown by the dashed line. All figures have rotational symmetry about a horizontal axis through the center. (a)γ = 2 vibration (2+ state); (b) γ = 3 vibration (3- state); in (a) and (b) the neutrons and protons move together, (c) γ = 1 (1- state), in which the neutrons and protons move in opposite directions. At one extreme of the vibration, the neutrons are displaced to the left and the protons are displaced to the right as shown, while at the other extreme of the vibration their positions are reversed.

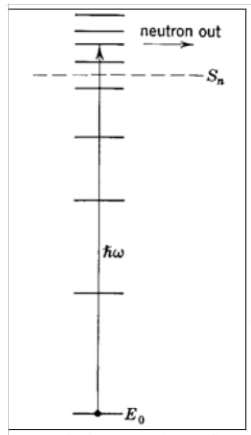

Figure 7. Schematic picture of the photonuclear effect with emission of a neutron [the (γ, n) reaction].

Photodisintegration

Atomic nuclei have been disintegrated by high energy photons (Figure 7). The process is called *photodisintegration*. These can be gamma rays of one energy (gamma rays are naturally occurring while X-rays are man made but both are photons) or gamma rays from a source which yields a continuous spectrum of energies, including a high-voltage X-ray tube as well as from a betatron.

The best known gamma reaction is the photodisintegration of the deuteron,

$$_1H^2 + \gamma \rightarrow {}_1p^1 + {}_0n^1$$

If the Q of a reaction is negative (A negative Q value means that kinetic energy must be brought into the nucleus to make the reaction proceed. This kinetic energy is converted to mass. Such a reaction is called endothermic. The reaction cannot proceed until the photon brings in enough energy to satisfy conservation of energy. This means that the cross section for a gamma reaction is 0 until the energy of the projectile is at least equal to Q. The energy of the projectile for which the reaction first has a nonzero cross section is called the *threshold* energy for the reaction. The threshold of the reaction is that energy of the gamma ray which is just sufficient to break the proton-neutron bond; *i.e.*, the gamma ray must deliver an energy equal to or greater than the binding energy of the system.

Photodisintegration usually gives rise to neutron emission, *i.e.*, to a (γ, n) reaction by the nuclei which have been raised to excited states by the absorption of these photons (Figure 8). The energy of the gamma ray for which neutrons are first observed to be ejected is the binding energy of the neutron. The (γ, n) cross section becomes very large for most nuclei, for gamma energies between 10 and 20 MeV. This effect, called the *giant resonance*, is responsible for much of the neutron background of

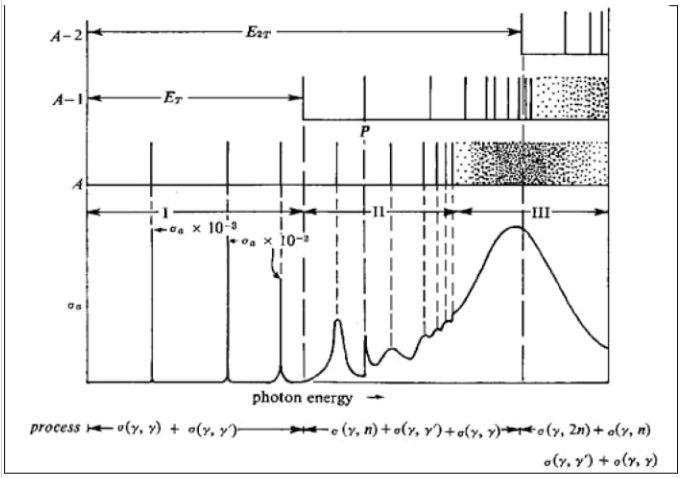

Figure 8. The photon absorption cross section for an idealized nucleus. Region I is that part of the energy scale below the particle thresholds where absorption is into discrete energy levels. Region II is the energy range above the binding energy where structure may still exist in the absorption cross section. In region III the absorption cross section is smooth. The processes that can take place are indicated along abscissa; σ(γ, n) here stands for the cross section for nuclear emission. The energy levels in the nucleus *A*, *A*-1, and *A*-2 are illustrated at the top of the diagram. The binding energies for one and two particles are designated by E_T and E_{2T}. The level P_1 in A-1 represents a parent of the ground state of nucleus A^6.

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high-energy gamma ray machines. The giant resonance occurs in all nuclei and is viewed as a general property of nuclei. Its width is 3-10 MeV and it is located between 13 and 18 MeV for medium and heavy elements and near 20 MeV for light elements.

Baldwin and Koch (1945) were able to determine the threshold for photodisintegration of several different nuclei in the range of atomic numbers Z = 6 to Z = 47 (Figure 9). Sher, Halpern, and Mann determined the thresholds of many (γ, n) reactions. The threshold value of the (γ, n) reaction with any isotope of mass number A will give the binding energy of the neutron in the nucleus of the isotope of mass number A-1.

The energy necessary for photodisintegration of a nucleus is calculated from known nuclear masses (Figure 10). It is obviously easier to remove one particle than several from the nucleus. As a result we find that Eγ must be >5 MeV for photodisintegration of heavier nuclei. For 10< Eγ <40 MeV the photon wavelength is comparable to the nuclear vibrational motions (so-called dipole vibrations, because the neutrons and protons are assumed to vibrate in separate groups). This is known as the giant resonance region, because the total cross section for heavier nuclides goes up to hundreds of millibarns. For higher Eγ, nucleons may be expelled, the main reactions being (γ, *n*), (γ, 2*n*) and (γ, *np*) in descending importance.[8]

Reaction	Threshold (MeV)
D(γ, n)	2·22
Pt^{195}(γ, n)	6·13
Bi^{209}(γ, n)	7·39
Au^{197}(γ, n)	8·05
Cu^{63}(γ, n)	10·8
C^{12}(γ, γ)	15·1

Figure 9. The neutron binding energies are taken from V. Ashby and H. Catron, UCRL 5419.

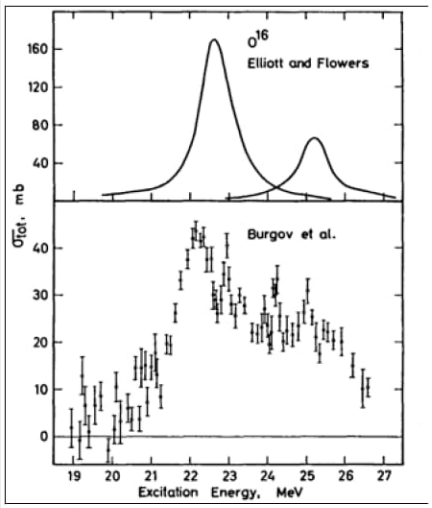
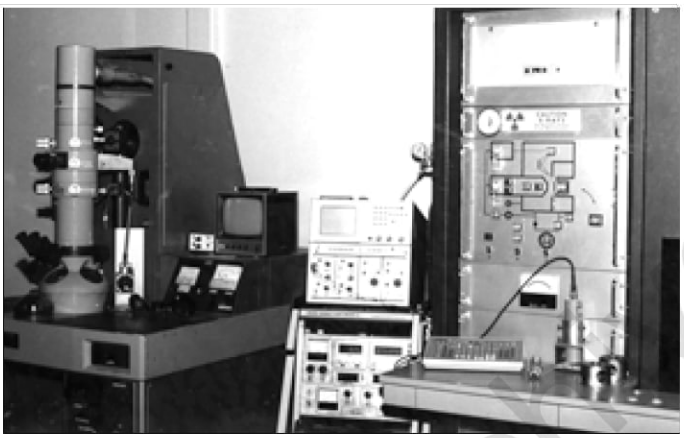


Figure 10. A comparison between calculated values and measured values as calculated by Elliott and Flowers for O^{16}.

Flux and Cross-Section:

The number of photons per square centimeter per second incident on the target is called the *flux*. When a target is exposed to a flux of photons, the number of nuclei reacting is proportional to the flux, and to the number, N, of target atoms. Then R =σ ϕ N, where R is the reaction yield and σ is a constant characteristic of the nuclear reaction in question. σ has the dimensions of an area, and is therefore usually called the cross section of the reaction. We can picture each target atom as a disc of area σ, with reaction occurring every time an incident photon strikes the disc. In some circumstances σ is indeed equal to the physical cross section of the nucleus. Tables and graphs of photonuclear cross sections exist and may be used to calculate reaction yields. In such tables σ is usually expressed in barns or millibarns, one barn being 10^{-28} m^2.



Nuclear transmutation source (right); Nuclear Spectrometer (center); Carl Zeiss Electron Microscope (left).

Cross sections vary with the energy of the incident photon, and the tables usually indicate this variation (Figure 11). Where there is a threshold energy, σ is zero below the threshold, and rises to positive values above the threshold. The relation between cross-section and energy is called the *excitation function* of the process.

Reaction Rate:

For a photonuclear reaction in which a species A is converted into a species B: A → B. If the cross-section of this reaction is σ, then nuclei of A are destroyed (burnt out) at a rate $\sigma \phi N_A$, while those of B are produced at this same rate:

$$R = -dN_A/dt = dN_B/dt = \sigma \phi N_A$$

This equation is of the same form as that for radioactive decay of A to B, but with σ ϕ, in place of the disintegration constant λ. There is indeed an extensive analogy between the kinetics of radioactive decay, and kinetics in a constant flux of nuclear photons, and the equations concerned are closely similar.

If the target species A is radioactive, then both nuclear reaction and decay contribute to its disappearance. The rate of loss is the sum of the two terms:

$$-dN_A/dt = \sigma \phi N_A + \lambda_A N_A$$
$$= (\sigma \phi + \lambda_A) NA$$

If ϕ is constant, there will be a corresponding effective half-life of $0.693/(\sigma \phi + \lambda_A)$. Again, if the product B is radioactive it will be produced at a net rate:

$$dN_B/dt = \sigma \phi N_A - \lambda_B NB$$

provided that we can neglect loss of B by further nuclear reaction.

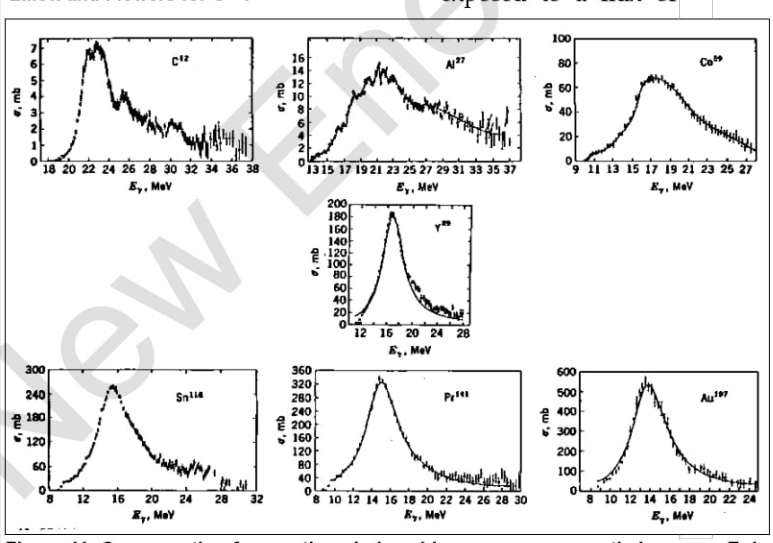


Figure 11. Cross section for reactions induced by gamma rays vs. their energy E_γ in various nuclei. Actually these data include only reactions which neutrons are emitted, for example, (γ, n), (γ, 2n), (γ, pn), but these account for nearly all the reactions in most cases. Note that these cross sections are dominated by resonance due to the 1^- state vibration.[7]

Waste Management

The goal of transmutation for waste management purposes is to convert a long-lived radionuclide that is potentially troublesome at a waste disposal site to a shorter-lived or stable nuclide by exposing the troublesome nuclide to a high flux for a sustained time. This has

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the effect of reducing the long-term toxicity of the waste because most of the waste constituents would then decay to a non-radioactive nuclide in a short time.

Chemical processes are an integral part of any transmutation scheme to separate the radioactive components of the wastes into high purity fractions that can then be made into transmutation targets. Such targets would be irradiated in a flux having sufficient intensity and energy such that the radionuclides in the targets would either be transmuted or fissioned into stable elements or isotopes with substantially shorter half-lives at an acceptable rate.

At present, there are only four industrially demonstrated separations processes applicable to reactor wastes meeting the needs of transmutation. These processes are designed primarily for the concentration and purification of plutonium, but only the PUREX process is well established in current worldwide use. In the past, the British have used a solvent extraction process called BUTEX, the French have used ion exchange, and there have been a number of ion exchange processes that have had limited production use in the isolation of minor actinides.

Several potentially applicable separations processes based on new solvents, such as the TRUEX-CMPO process, and new ion exchange materials are in various conceptual or laboratory scale development stages. Such advanced aqueous processes have been proposed to achieve high decontamination factors but have not been demonstrated at the full engineering pilot-plant level.

A commercial waste transmutation facility would require head-end treatment of spent reactor fuel to chop and dissolve the fuel, followed by separation of the transuranics and selected fission products. Either aqueous or nonaqueous processes may be used for the initial separations. The well-established PUREX process may be used for this separations step. This would be followed by an aqueous separations process using advanced technology such as the TRUEX process. A full scale separations system may be designed with high confidence for overall separations process losses of less than 0.1%.

Solid metals may be separated by pyrochemical process. Pyrochemical processes might require less capital expense than aqueous ones because the volume of shielded space can be smaller as well as the reduction in the size of the plant and equipment needed.

Conclusion

By introducing energy to the nucleus greater than the binding energy, we can initiate a nuclear reaction that results in a radiochemical transmutation. By proper design, these reactions may be used to transmute long-lived radioactive waste products into short-lived and manageable products.

Examples of Transmutation After Treatment

Isotope	Normal Time Required To Become Stable	Time to Decay to Stable After Treatment
Strontium-90	291 years	IMMEDIATE
Iodine-129	1,700,000,000 years	IMMEDIATE
Technetium-99	2,120,000 years	43 days
Cesium-137	302 years	130 days

We have available to us a method for treating radioactive waste products in such a way that leaves the half-life manageable. This process is available to us now, without development of new technologies. The treated waste products, due to their inherently short half-lives, become heat sources. These heat sources may be utilized in conversion systems for producing electrical power, *i.e.*, for powering the treatment equipment itself. There is also the neutron flux produced as a waste product of the treatment process. This neutron flux may be used for activation as well as neutron-transmutation of radioactive waste products, such as,

$Tc^{99} + n \rightarrow Tc^{100}$ (16 second) $\rightarrow \beta + Ru^{100}$ (stable)

$I^{129} + n \rightarrow I^{130}$ (12.4 hr) --> $\beta + Xe^{130}$ (stable)

$I^{127} + n \rightarrow I^{128}$ (25 min) --> β Xe^{128} (stable)

Therefore, all that remains is to apply this technique. It should also be noted that application of this process should boost the nuclear power industry by providing a cheap, effective method for disposal of the reactor waste products.

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Dr. Brown at the controls of the nuclear transmutation system. Nuclear reactions are induced causing neutron emission resulting in stable or short-lived radioisotopes.

Dr. Brown is well known for his contributions to isotopic generator research, especially related to direct energy conversion. He is a research scientist with more than 15 years experience at public and private research facilities. He is the member of several professional societies including The American Nuclear Society, and the American Institute of Aeronautics and Astronautics. Dr. Brown holds five U.S. patents and many others worldwide. His conference presentations include: Symposium on Space Nuclear Power and Propulsion-NASA; National Technology Transfer Conference - NASA; Intersociety Energy Conversion Engineering Conference; American Nuclear Society. He is the author of several periodical articles as well as six technical books.

The following report was received from Dr. Paul Brown:

"This memo is to summarize the experiment run on July 20, 1998. This experiment was successful in that we clearly displayed evidence of transmutation. The experiment was designed with two purposes in mind, namely, to demonstrate transmutation and to test the equipment as assembled.

"Using a micro-Curie cesium-137 source, placed in the treatment chamber and treated with a 40 mAmp beam, we increased the activity of this source from 220 kcpm to 1000 kcpm, and from 500 micro-R to 2000 micro-R, for an increase in activity of 450%. We are now monitoring the decay scheme of the source which appears to be following the predicted 13 day half-life.

"The beam flux density was on the order of 2 $X10^{15}$ photons/cm^2-sec. The equipment appears to function well. Beam current is sufficient.

"This testing was qualitative and successful. Next we will run a series of quantitative tests to determine treatment rates as a function of beam intensity and beam current for various radioisotopes."

Paul Brown, July 22, 1998

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DEVICE AND PROCESS TESTING UPDATES

Get an 1,800 square foot warehouse condominium, add tons of stacked back issues of *Infinite Energy* magazines waiting to be delivered to the unenlightened, add many more tons of research equipment, add many tools and supplies from the plumbing and electrical trades, scientific instruments and weird devices and processes to be tested, then mix into this "toy store" two relatively sober engineers linked to the wilds of the Internet, and what do you have? Why, the New Energy Research Laboratory (NERL) here in Bow, New Hampshire.

When we outgrew our previous publication office and acquired our new two-floor facility in the adjoining building of the Bow Technologies Center, we decided to make the first place a dedicated laboratory. We had been limping along with a less than dedicated full-time approach to testing machines and cells, although Chris Tinsley in the UK had been fairly dedicated to that mission, until his untimely death a year ago. Sure, we had the occasional part-time volunteer help, and no dearth of gape-mouthed visitors, but the lab had previously been under serious time-sharing stress with the publication schedule of the magazine. It still is.

Since last issue, ex-Federal Aviation Administration (FAA) electrical engineer Ed Wall has arrived and is now working a full-time (80-hour) week in the NERL. We joke that he is having so much fun working in Wonderland that we should have him insert his credit card into a meter at the door to pay Cold Fusion Technology, Inc., rather than the other way around! Work expands to fill up time. More and more devices keep appearing on our doorstep and both Ed and I (mostly Ed), struggle to do each of them justice.

This report should be taken as a modest interim discussion of some of the activities with which we are engaged. The NERL is in a period of readjustment to the working paces of a combined team of engineers and consultants. Some day the team will be larger. We hope it works as well as it does right now. We never want to be a Really Big Company that does not have first and foremost Fun doing what it is is doing. On the other hand, we are impressed with the seriousness of our mission and don't want you to think that we are not hell-bent to tie up loose ends and button down the validity of some apparently potent over-unity technologies.

We multiply our efforts, as we have said before, by relying on others to perform those testing efforts for which we not have immediate access to the right equipment—or to engage in parallel testing. We appreciate the fantastic input we get from the Vortex-l electronic discussion forum. In particular, Scott Little and Dr. Hal Puthoff of EarthTech International in Austin, Texas have been very cooperative and helpful.

For now let us provide a brief run-down of what is going on hither and yon on the testing front:

1. Kinetic Furnace of Kinetic Heating Systems, Inc. of Cumming, Georgia (Featured in Issue #19)**:**

At NERL we have further tested the second unit of the Kinetic Furnace that we received. Again, we obtained disappointing results that are in the range COP= 1.01 to 1.15—too low to call guaranteed over-unity. We still do not understand the differences between conditions in Bow and those in Georgia. So, we attempted to use various different sources of water, so far without seeing increases in COP.

Kinetic Heating Systems has acquired a more professional air-flow monitoring system than its Dwyer pressure gage. Still, the company reports significant over-unity power production. The particular device is an Air Data Multimeter (ADMA60), made by Shortridge Instrument Company, Inc., of Scottsdale, Arizona. The following are three tests that Kinetic Heating Systems has recently performed:

Test #1: August 17, 1998
- 200 V, 16.5 amp without blower fan, 19.5 A with blower fan on
- 3.6 kW-hour input energy = 12,287 Btu
- 1,059 CFM air flow
- $\Delta T = 18.5$ °F ($T_{in} = 87$ °F, $T_{out} = 105.5$ °F)
- Output energy = 21,159 Btu
  C.O.P. = 1.72

Test #2: August 18, 1998
- 200 V, 16.5 amp without blower fan, 19.5 A with blower fan on
- 3.6 kW-hour input energy = 12,287 Btu
- 1,059 CFM air flow
- $\Delta T = 22.2$ °F ($T_{in} = 83$ °F, $T_{out} = 105.2$ °F)
- Output energy = 24,671 Btu
  C.O.P. = 2.0

Test #3: August 20, 1998
- 3.6 kW-hour input energy = 12,287 Btu
- 1,049 CFM air flow
- $\Delta T = 23$ °F ($T_{in} = 79$ °F, $T_{out} = 102.0$ °F)
- Output energy = 26,077 Btu
  C.O.P. = 2.12

Ralph Pope informs us that he intends to put a working Kinetic Furnace in an RV and drive it up to our lab in Bow, NH. He wants to see if he can find out first hand what kind of changes might be happening along the way to make the system performance degrade.

2. Catalytic Fusion of Dr. Les Case, of Fusion Power, Inc., Newfields, New Hampshire (Featured in Issue #19)**:**

In a major development, Russ George in California in collaboration with Dr. Les Case, has reported the build-up of helium-4 (^{4}He) levels as a function of time time in an active cell based on Dr. Case's design. The helium-4 level apparently exceeded by at least a factor of two the possible background helium contamination from any conceivable leakage into the active cell—the cell with deuterium gas. There was no such build up of helium-4 in the ordinary hydrogen control cell, which required nominally more heater power to maintain the small temperature. It is disappointing that Dr. Case has still not succeeded in making a self-heating, self-sustaining cell. But he continues to try.

3. Mizuno-Ohmori Effect (Featured in Issue #20):

At NERL we have done no testing of Ohmori-Mizuno process since Issue #20. We were called by Prof. John Dash of Portland State University in Oregon, who had tried the experiment, but not to generate excess heat in the intense plasma discharge regime. Professor Dash, an expert materials scientist who has observed transmutations on cathodes in other experiments, tried the Mizuno-Ohmori system with tungsten cathode. After running, he found deposits of chromium on the cathode

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that he could not explain by environmental contamination.

Scott Little at EarthTech International was unable initially to obtain excess power with his set up of the Ohmori-Mizuno experiment. However, as we went to press he was finding some startling differences in heating of his tungsten electrode when he switched to thoriated (2% thorium content) material! In addition, engineer Jan Roos of Massachusetts came up with a simpler circuit for generating the DC power input to the cell. Stay tuned for further developments to be reported in Issue #21.

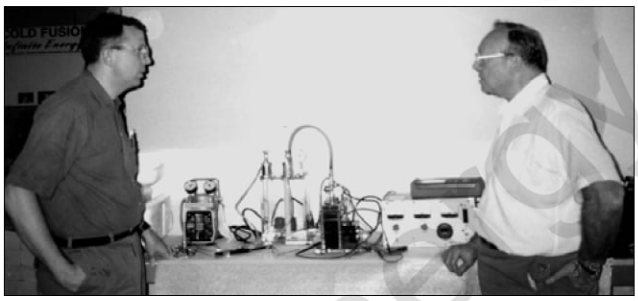
4. Nuclear Augmented Combustion, of Crystal Energy, Inc. (Featured in Issue #18):

Tom Knudson of Crystal Energy Technology, Inc. has told us that a U.S. trucking company in Tennessee has agreed to a licensing agreement to use its mileage-enhancing and pollution-reducing lithium-additive in its truck fleet. The company had earlier tested the additive and found it beneficial and potentially cost effective to use.

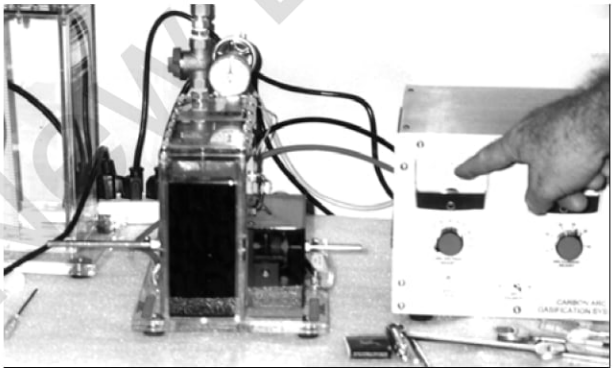
A large U.S. corporation involved in the power-generating gas turbine industry is still scheduled to test the Crystal Energy additive.

3. CarboHydrogen™ Gas of DW Research, Colorado Springs, Colorado and AquaFuel™ of Toups Technology Licensing Corp., Largo, Florida. (Featured in Issues #9, #10, and #19)**:**

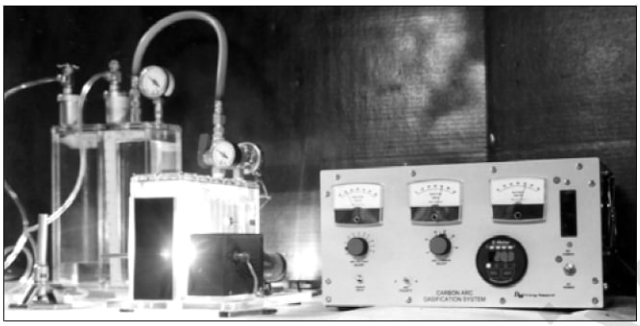
The carbon underwater arc technology of these two companies, which generates a gas that combusts with very low pollution, is potentially an over-unity technology. Preliminary measurements made by DW research, published earlier in *IE* suggest this strongly. With the encouragement of our company, DW Research has developed a commercial demonstration unit for generating the gas for laboratory studies —*not* for large volume production. The beautifully assembled device, which DW Research intends to market for about $9,500, has a highly stable computer-controlled arc and a calibrated gas metering collection chamber. It can be used in conjunction with a coiled copper tube calorimeter for measuring the heating value of CarboHydrogen™ gas. Wilbur Dammen of the company visited our laboratory for several days to explore the functionality of the device with us.



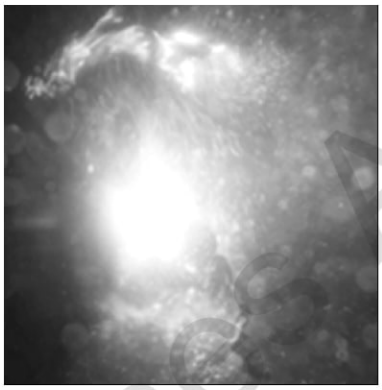
Ed Wall (Left) and Wilbur Dammann of DW Research in the New Energy Research lab (NERL) here in Bow, New Hampshire. The newly delivered computer-controlled arc to produce CarboHydrogen gas is at the center (dark chamber with UV shield in front), the control apparatus is to the right, and the gas collection vessel is to the left. (Photo: EFM)



The core of the DW Research demonstration unit consists of a chamber with a sugar solution in which the computer-controlled arc produces CarboHydrogen gas. (Photo: EFM)



An intense glow emanates from underwater electric arc within the DW Research reactor vessel. (Photo: EW)



Close-up of unfiltered underwater arc. (Photo: EW)

For its part, Toups Technology Licensing Company has provided NERL with several cylinders of compressed AquaFuel™, which we will also test for its gas heating value, but in an air tunnel that can accommodate larger flames than the smaller coiled-tube calorimeter.

4. HydroSonic™ Pump of HydroDynamics, Inc. of Rome, Georgia:

Installation of an expensive modification to the NERL building electric power supply system is nearing completion. This will allow us to test the COP of the Griggs hot water-producing HydroSonic Pump. The particular model that we obtained had a COP of 1.15, as measured by Griggs before it left the factory. It is powered by a 75 HP electric motor. We intend to accurately measure the mechanical input power to the rotor, as well as the electric input power. Conservative measurement of the output power is obtained by simple flow calorimetry.

5. Thorium Transmutation Cell of The Cincinnati Group, Cincinnati, Ohio. (Featured in Issue #13/14):

Though this cell has been amply evaluated as a confirmed transmutation unit, we want to see the effect here in Bow, now that we have the people power to measure it. The Cincinnati Group intends to send us a newly modified version of their commercial cell for our testing.

6. Brown's Gas Investigations (Proprietary Technology):

We have taken delivery of a Brown's gas generator built for welding applications, on which we are performing various tests for a company that is interested in studying the technology. For the time being, this work is proprietary and very time-consuming, but we will be happy to publish our findings. Yes, it does weld steel to ceramics and it a very lovely technology. We are interested in the various anomalies that *may* be observable with our generator of this unusual gas.

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Cold Fusion Revisited

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ABSTRACT

A collection of recent studies of what is incorrectly called "Cold Fusion" shows the present status of the phenomenon and provides some explanations for the claims. An understanding of many claims continues to improve while new discoveries still challenge the most creative theories. A case is made to support a new field of study involving chemically assisted nuclear reactions.

I. BACKGROUND

Nucleons and electrons are separated by vast differences in energy and in the time needed for its release. As a result, chemistry and nuclear physics occupy two different worlds. Observations of Profs. Stanley Pons, Martin Fleischmann, and Mr. M. Hawkins (University of Utah, U.S.) and independently by Prof. Steven Jones *et al.*[2] (BYU, U.S.), suggest that a bridge exists between these two worlds. Thus was born what is conventionally called "Cold Fusion," an unfortunate name. Because no accepted theory properly supports the claims and because much experimental data were poorly presented and hard to duplicate, most scientists continue to reject the notion. Adding to the difficulty is the conflict between the picture of nature these claims would imply and the dearly held conventional understanding.

In spite of good reasons for skepticism, a few scientists succeeded in duplicating the observations. Many of these studies are on going at the present time, especially outside of the U.S. This world-wide effort is underway in at least eight countries involving hundreds of scientists and tens of millions of dollars per year. Very persuasive results supporting the initial claims, as well as many new ones, have created a need for a fresh look.

Because the phenomenon combines solid-state chemistry and nuclear physics, the backgrounds and expectations of potential readers are vastly different. Consequently, a level of detail required to be persuasive to everyone is not possible in a brief review. So, only a sampling of experimental observations and theoretical models are presented to give a general background. I hope the reader will take the trouble to read other sources of information before reaching a conclusion. Unfortunately, much of the supporting evidence is still published only in conference proceedings because many scientific journals have been reluctant to publish papers about the subject. Consequently, peer reviewed information, the core of conventional scientific evaluation, is largely missing. The reader will, to some extent, have to evaluate some of the claims using their own good judgment. Six books describe the history of the field, some with objectivity[3-6] and some containing serious distortions.[7,8] Several general, peer reviewed scientific reviews are available.[9-12] These sources can be consulted to understand the background, both pro and con. A complete bibliography can be obtained from Dieter Britz[13] or Hal Fox[14]. Over 2000 publications now address issues related to the field.

The field has expanded beyond the original claims and can now be called "Chemically Assisted Nuclear Reactions" (CANR) instead of "Cold Fusion." Production of anomalous energy far in excess of any conventional chemical source, production of many elements not present in the original environment, and production of radiation that can only result from nuclear reactions are all characteristic of the field. Each is found to occur in a variety of materials using numerous techniques when deuterium as well as normal hydrogen are present. The nuclear products include helium, tritium, and various isotopes resulting from several types of transmutation. Radiation in the form of neutrons, gamma rays, X-rays and charged particles have been detected, all at very low levels compared to the rate at which energy is produced. A change in radioactive decay rate of tritium, produced by the physical environment, also has been proposed.[15] The extraordinary nature of this growing list adds to the challenge of presenting a review that encompasses the entire field without sounding so incredible to cause alienation of the reader.

To understand CANR, we need to address the issue of why the claims have been so hard to believe. Disbelief is based on the experimental results being inadequate and in conflict with conventional understanding of nuclear interaction. In addition, many failures to produce excess energy, especially those at several high-profile institutions,[16-18] gave the impression that the phenomenon could not be reproduced at will.[19] At one time this was true. As the variables have been better understood, success in producing energy as well as nuclear products has improved. Certain methods and results are now highly reproducible in the hands of skilled experimenters. Many negative results are known to be caused by failure to understand and control important variables. For example, the effect will not occur in an electrolytic cell using a palladium cathode when too much light water (H_2O) is present in the heavy-water (D_2O). Many early studies used open cells which readily absorbed H_2O from the atmosphere. Added to these experimental problems, is the highly variable nature of palladium such that only a small number of samples will have the necessary characteristics. Of course, random error can still play a role, but a growing understanding indicates error is not the main cause of positive results. Several of the better done studies will be described in detail.

Scientists quite rightly have asked to be shown nuclear products along with energy production before a nuclear source is accepted. This request has now been honored with the detection of helium (^4He) by several laboratories, as described in a later section. In addition, a growing body of data now support production of several nonradioactive nuclear products not associated with a fusion reaction, so-called transmutation products. Detection of such products is claimed in several vastly different chemical environments including, surprisingly, living systems. Of course, some of these claims have simple explanations, but not all.

When conventional methods are used to produce fusion at high temperatures in a gas plasma, in the Tokamak for example, neutrons and tritium are produced in equal amounts and at high levels. Such expectations fueled early efforts to detect these products during CANR. Lack of success added to widespread skepticism but also demonstrated that whatever occurs is not conventional fusion. CANR apparently does not generate these products in the expected ratio or quantities. Indeed, anomalous heat is seldom associated with tritium production

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and very few neutrons are detected. These contrasting behaviors are summarized in Table 1.

Tritium is one isotope whose presence is difficult to mistake. If its formation by CANR can be demonstrated, a powerful support for the general idea would exist. For this approach to be successful, the tritium must be shown not to result from another process. The detected tritium could have entered the cell from the environment or be a contaminant in palladium, two of the more common reasons given for rejecting the nuclear explanation. However, tritium has been produced in such large quantities and in such isolated environments to make such prosaic explanations very difficult to support. Except in certain areas of government laboratories, tritium is very rare indeed. Numerous studies have shown that commercial palladium does not contain significant tritium.[20] Therefore, it is no longer appropriate to dismiss tritium claims as being caused by contaminated palladium. These arguments will be developed in more detail in a later section (Section 2.2.1).

Although neutron emission is well below the expected rate, it is not completely absent. Many studies have detected small emissions with energies corresponding to the conventional fusion reaction as well as neutrons produced by other sources. Because the emission rates are close to background and are erratic, much doubt still remains as to their source.

Helium-4 production in a hot plasma by fusion is rare and always accompanied by 24 MeV gamma emission. Absence of this radiation is a major reason why many people reject this claim when applied to CANR. They fail to consider at least five other reactions which result in helium without accompanying gamma radiation, as listed in Table 2. Each of these reactions has a theoretical basis and, in a few cases, some experimental support. Therefore, helium cannot be rejected as a nuclear product just because gamma radiation is absent.

Well established theory predicts that the coulomb barrier can not be overcome using the small energies available within a chemical structure. Clearly, if fusion or any other nuclear reaction is to occur at all, a mechanism must exist that does not require high energy, that does not produce the usual reaction paths, and that is able to absorb the resulting nuclear energy without significant radiation. This is a lot to ask of any process. To make matters worse, energy production from light hydrogen and the newly discovered transmutation reactions introduce a whole new set of problems that tax any explanation. We can either accept the conventional viewpoint and throw out all experimental observations involving CANR, or we can search for new theories that consider the novel characteristics of the chemical environment while keeping most claims. In other words, the results obtained at high energy are correct for the environment in which they were obtained, and the CANR results are also correct for their environment. Most of the new explanations take this approach. No lack of possibilities exist. A few will be discussed later in the paper. The challenge is to demonstrate which one, if any, is correct. Although it is satisfying to believe one explanation fits all, the increasing variety of nuclear reactions and chemical environments make this approach increasingly difficult to justify.

TABLE 1
THE NATURE OF THE FUSION REACTION

d + d	Hot Fusion >2 KeV	Cold Fusion <1 eV
⇒ t(1.0 MeV) + p(3.05 MeV)	(50%)	(<0.1%)
⇒ ^{3}He(0.82 MeV) + n(2.45 MeV)	(50%)	(<<10^{-6}%)
⇒ ^{4}He + γ (24 MeV)	(<10^{-3}%)	(≈100%)

d + t ⇒4He + n(14MeV)

TABLE 2
Reactions Producing Helium with No Gamma Emission

1. Multiple fusion to produce helium
   $d + d + d \Rightarrow {}^4He + d$
   $d + d + d + d \Rightarrow 2\ {}^4He$
2. Reaction with boron impurity to produce helium
   $d + {}^{10}B \Rightarrow {}^4He + {}^8Be$
   ${}^8Be \Rightarrow 2\ {}^4He$
3. Reaction with lithium impurity to produce helium
   $d + {}^6Li \Rightarrow {}^8Be \Rightarrow 2\ {}^4He$
4. Fusion with a metal leading to alpha decay
   $d + {}^nM \Rightarrow \alpha + {}^{(n-2)}M$
5. Collapse of deuterium atom to produce beta decay and helium
   $d + e^- \Rightarrow 2n$
   $2n + d \Rightarrow {}^4H \Rightarrow 4He + e^-$

TABLE 3
Methods Used to Produce the CANR Effect

Electrolysis
Gas reaction
Electric discharge
Phonon conduction through semiconductors
Cavitation involving bubble formation
Mechanical changes
Sudden decomposition of hydride
Biological systems

II. EXPERIMENTAL

The CANR phenomena has expanded from simple electrolytic loading of palladium and titanium with deuterium to include the methods listed in Table 3. Each method has produced unusual results when both light (H) and heavy (D) hydrogen were used. Unfortunately, only a few of the methods have been replicated by independent investigators. Most of the methods will be discussed starting with electrolytic production of heat. Recent work not covered by previous reviews will be emphasized. Radiation and nuclear products will be discussed in separate sections.

II. 1. Electrolysis

Electrolysis is the most widely used method to produce the claimed CANR effects. When a current is passed through a water-based electrolyte, hydrogen (or deuterium) is formed at the cathode (negative electrode) and oxygen is formed at the anode (positive electrode). The metal used as the cathode reacts with the hydrogen to form a hydride. Usually palladium is used as the cathode with D_2O, and various forms of nickel are used with H_2O. Hydrogen with palladium and deuterium with nickel have not been found to produce unusual results. Other metals have given some claimed success but without the necessary replication. For reasons that are not yet fully understood, certain batches of metal are much more likely to show the CANR effects than are others. Because these additional variables exist, negative results can not be used to off-set positive results such as would be appropriate if the positive results resulted only from random error, as some skeptics have suggested.

II. 1.1 Heavy-Water

In the case of palladium electrolyzed in D_2O, the hydride

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formed is β-PdD_{1-x}, a face-centered-cubic structure containing vacancies (x) in the deuterium sublattice. Because the effective deuterium activity and concentration are both very high at the cathode surface, normally unstable hydrides can also form in a region which is microns deep. In addition, the surface region is rich in deposited impurities which influence the deuterium activity and phase stability of various compounds.[21] Consequently, the active chemical environment is highly variable, accounting partly for the difficulty in reproducing the claims. For these reasons, an understanding can not be based only on the chemical environment known to exist in β-PdD, as has been done extensively in the past.

Over 50 studies reporting repeated examples of excess energy production have been done, most of which have been published at least in conference proceedings. Studies published before March 1996 are reviewed by Storms.[11] To understand and eventually accept the claims for heat production, it is necessary to understand the various possible errors in calorimetry and how they have been eliminated. For example, open cells were extensively used during the early studies in which an uncertain recombination of the D_2 and O_2 gases could take place, as pointed out by Jones *et al.*[22] This process would cause a variable amount of energy to be captured by the calorimeter, resulting in what might be interpreted as excess energy. Most studies now use closed cells or measure the amount of recombination. Another early issue was the effect of temperature gradients within a nonstirred calorimeter.[23] To answer this criticism, Pons and Fleischmann,[24] Klein *et al.*,[25] Takahashi *et al.*[26] and Guruswamy *et al.*,[27] among others, demonstrated that mixing produced by electrolytic generated gas bubbles is sufficient to eliminate serious gradients in their cells. Not given much attention is the effect of the stagnant water layer at the cell wall on the thermal conductivity of the wall. The magnitude of this layer is very sensitive to the flow patterns within the cell. Consequently, the accuracy of simple isoperibolic calorimetry can be compromised by changes in stirring rate and by changes in the amount of bubbles generated. In addition, calibrations using internal heaters, where bubbles are absent, can not be applied to the electrolytic conditions where bubbles are present. It is, therefore, difficult to evaluate claims based on calorimeters stirred only by bubbles or when the stability of the mechanical stirring rate is uncertain. In contrast, some workers use calorimeter designs that are completely immune to the effect of temperature gradients such as flow calorimetry, double-wall isoperibolic calorimetry,[28,29] and devices based on the Seebeck effect.[30,31]

In their original studies, Profs. Pons and Fleischmann used a calorimeter requiring a rather complex mathematical analysis, thereby opening the door to easy rejection. Several independent analyses were made to evaluate their claims, the most detailed being a paper by Wilson *et al.*[32] This and other criticisms are answered by Pons and Fleischmann in several subsequent publications[24] and by several other workers.[33-35] In addition, an independent study by Lonchampt,[36] using an identical calorimeter, duplicated the Pons-Fleischmann claims for anomalous energy. Although the heat measurements by Pons and Fleischmann can be analyzed in different ways to give slightly different results, their conclusion for excess energy production has been supported.

One extensive study done at SRI (Stanford Research International) stands out for its completeness and its use of state-of-the-art equipment and methods.[37] EPRI (Electric Power Research Institute) invested over $6M to give us this information, and the New Energy Development Organization (NEDO) (Japan) has continued to support the work for the last three years after EPRI withdrew from the field. Figure 1 shows the

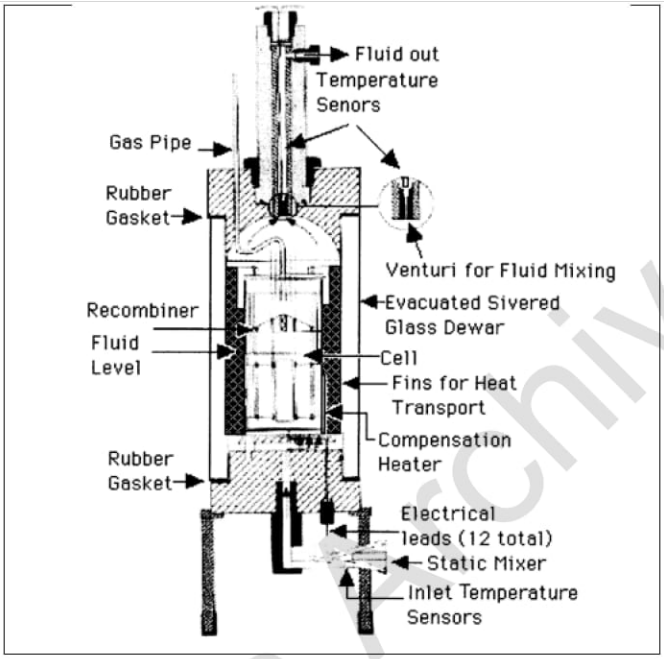

Figure 1. Calorimeter used at SRI.

cross-section of one of several flow-type calorimeters used for most of their studies. The cell is closed and contains a recombiner that returns to the calorimeter all energy invested in decomposing the water. Over 98% of the energy applied to the cell is recovered by the flowing water. Composition of the palladium cathode is determined from its change in resistance. An internal heater keeps the internal temperature constant when different electrolytic currents are applied and provides a means to check instrument stability. The device is used as an absolute calorimeter based on the flow rate and temperature change of the cooling fluid. This design has shown very stable behavior and has a sensitivity to energy change of ±10 mW although an uncertainty of ±50 mW is used when data are reported. Typical data are shown in Figure 2. This sample produced no excess heat until the current was increased at 400 h, thereby causing an increase in composition. Figure 3 shows how excess power relates to the average composition. Other workers have reported seeing this behavior as well. Applied current also has an effect as can be seen in Figure 4. Studies done at other laboratories, including the work of Pons and Fleischmann, are consistent with there being a critical current below which no excess heat is detected.[9] This behavior occurs even when a variety of sample forms and calorimeter types are used. Rejection of these studies must explain why the relationship between bulk composition and applied current is so consistent. Conclusions obtained from the work at SRI are summarized in Table 4. These conclusions are completely consistent with all published studies showing excess energy and each has been confirmed by several investigators. Unfortunately, all attempts to initiate the CANR effect using palladium suffer from a large fraction of failures. Adding to the confusion are the many negative studies which failed to consider even the basic requirements for success.

II. 1.2 Light-Water

Surprisingly, deuterium and hydrogen both produce excess energy and nuclear products. However, as expected, the nuclear products frequently are different.

Energy production using light water was first demonstrated by Mills *et al.*[38] Their reasons for making such an attempt were not based on an expected nuclear reaction, as described later. Energy production has been duplicated by other studies[11] but

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TABLE 4
Conclusions from Studies Done at SRI

1. The D/Pd ratio must exceed a critical value.
2. Current must be maintained for a critical time.
3. The current density must be above a critical value.
4. Inert palladium can sometimes be activated by adding certain impurities to the electrolyte.
5. The effect occurs in only a small fraction of samples but more often in certain batches than in others.

with evidence for a transmutation reaction being the source.[39] Recently, Clean Energy Technology, Inc. (CETI),[40] using nickel - coated plastic beads electrolyzed in a flowing electrolyte containing Li_2SO_4 in H_2O, have demonstrated production of significant energy. However, most efforts to duplicate this work have been unsuccessful for various reasons. Apparently, the nature of the metal coating on the bead is very important and difficult to duplicate even when the patent is consulted.

Light hydrogen has also been reacted as a gas with nickel to produce heat[41] and nuclear products and it has been used as an energetic ion to bombard nickel as described below. Preliminary claims for production of ^3He suggest[42] that d-p fusion may occur when deuterium and hydrogen are both present.

II. 2.1 Nuclear Products

II. 2.2.1 Tritium

The first nuclear product supporting the claims of Pons and Fleischmann was the claimed detection of tritium[43] in an electrolytic cell. This isotope is seldom produced when excess energy is detected and seems to be associated with the presence of certain impurities in the cell, copper being the more likely one, and the presence of dendrites on the cathode surface. When detected in anomalous amounts, the tritium exists in the electrolyte rather than as DT gas. In contrast, tritium previously dissolved in palladium as contamination is always released during electrolysis as DT gas.[44] This contrasting behavior demonstrates that observed tritium is not caused by contamination and that it was not formed within the bulk material. Only tritium formed on the surface can dissolve in the electrolyte. Unfortunately, tritium production has proven to be more difficult to duplicate than excess energy.

Two of approximately a dozen studies stand out in demonstrating the presence of anomalous tritium when heavy-water is used with palladium. Will *et al.*,[45] at the now disbanded National Cold Fusion Institute, used cells completely isolated from the environment which contained either D_2SO_4 or H_2SO_4 electrolytes and a recombiner catalyst. Tritium atoms in the range of $7x10^{10}$ to $2.1x10^{11}$ were found in four heavy-water cells while fewer than $4x10^9$ atoms (the detection limit) were present in light-water cells using palladium from the same batch. Other batches were below the detection limit in both cell types. The T/D ratio in the palladium was found to be significantly higher than in the electrolyte, indicating the tritium originated in the palladium. Careful analysis of many virgin palladium samples showed no indication of tritium contamination.[20] They conclude that the probability of the effect being caused by contamination was 1 in 2380.

Workers at Texas A & M[46] produced tritium in one cell using a LiOD electrolyte which was in series with a similar, nonactive cell. The production rate was sensitive to the applied potential (current) as shown in Figure 5. Production could be stopped by changes in current or by agitating the cell. The reaction could then be restarted. This behavior is totally inconsistent with tritium originating either as contamination or from the external environment. A total of 10^{15} tritium atoms were produced during the study compared to fewer than 5.1×10^9 atoms detected in unused palladium, the background of the detection method.

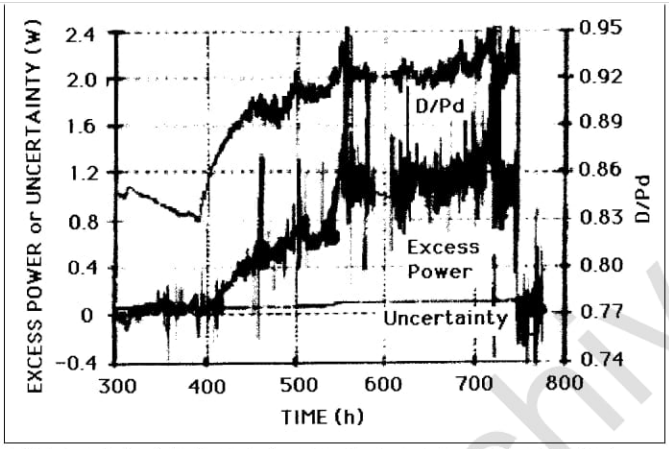

Figure 2. Behavior of a typical sample producing excess energy at SRI. The sample was electrolyzed for 400 hr without showing unusual behavior. Excess power was produced when the cell current was increased. The D/Pd ratio is the average bulk.

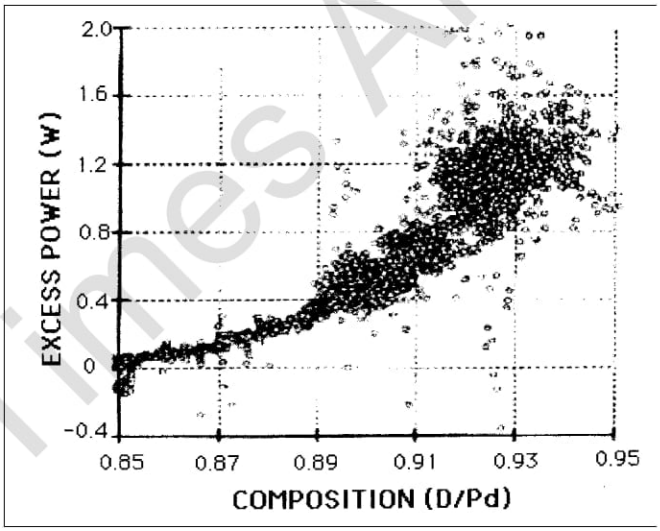

Figure 3. Typical effect of average bulk composition on the production of excess energy based on studies done at SRI.

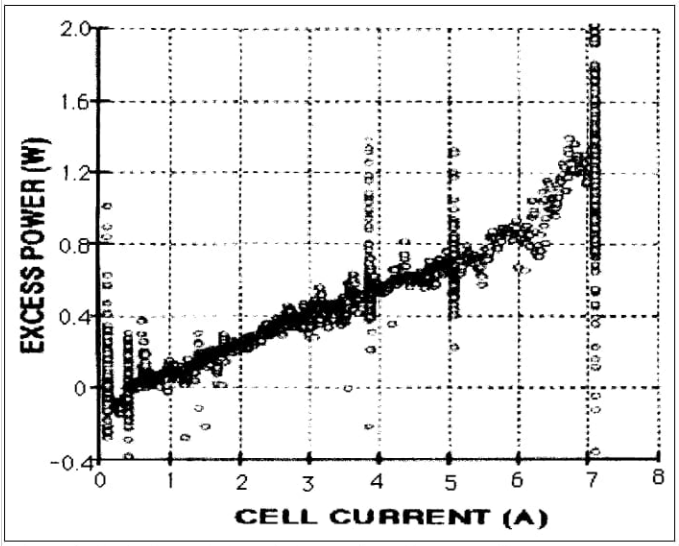

Figure 4. Typical effect of applied current on the production of excess power based on work done at SRI. The critical current varies between samples with a typical value being near 250 mA/cm^2.

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Claytor *et al.* (Los Alamos National Laboratory, U.S. [LANL])[47] continue to explore the production of tritium. A pulsed-gas discharge is used between a small palladium wire and an inert electrode in low pressure D_2 gas. The voltage is too low to initiate a normal fusion reaction known to occur at high voltages. All wires are previously outgassed to remove any tritium contamination. No tritium has been found in any commercial palladium even though scores of samples from many sources have been examined. This experience is consistent with several other detailed studies as noted previously. Tritium pick-up from the atmosphere, a very unlikely source even at LANL, is prevented by using a vacuum-tight, stainless steel apparatus. Deuterium gas is pumped through a loop containing the plasma cell, in which the discharge occurs, and through a Femtotech Tritium Gauge which provides a continuous measurement of tritium. Provisions are included to remove some gas, convert it to water, and measure its tritium content using standard scintillation techniques. Consequently, two independent methods are used to insure the claimed product is indeed tritium. Figure 6 compares the behavior of several samples exposed to D_2 as well as the behavior when H_2 or platinum are used in place of the active materials. Active samples begin producing tritium immediately after discharge is started. Changes in current or other operating conditions cause changes in the observed tritium production rate. Similar conditions produce no effect when D_2 is replaced by H_2 or when Pd is replaced by Pt, thus providing a null check. Like all experiences in the field, the ability to produce the effect is very sensitive to the nature of the palladium sample. For this reason, the results have been inconsistent. Nevertheless, certain batches of palladium or its alloys have a sufficiently high success rate to allow many variables to be explored. Of the many examples of tritium production, this work stands out as being the most difficult to refute. Although this work has not been published in a reviewed journal, it has been extensively reviewed at LANL and is available on the Internet.[47]

II. 2.2.2 Helium

Helium was recognized early in the field's history as being a likely nuclear product, but its difficult detection had to await the careful work of Miles *et al.*[48] Confirming studies using the electrolytic technique have been done at the University of Texas,[31] University of Roma La Sapienza[49] and at INFN in Italy, [50] and in Japan[51] using gas loading. In each case, care was taken to eliminate helium that might enter the cell from surrounding air. However, not all attempts to detect helium have been successful partly because excess energy is difficult to produce and partly because measuring small amounts of helium in deuterium is difficult. When helium is reported, the levels are lower than expected based on a fusion reaction being the sole source of measured energy. Unfortunately, the reported values are not the sum total of all helium, *i.e.* that contained both in the gas and dissolved in the palladium metal. Only one of the two sources is typically reported. Obviously, all helium needs to be considered when the results are compared to energy production. Alpha emission has also been detected[52] and recent claims for ^{3}He have been published.[42] The latter claim is being actively investigated by other workers. No gamma radiation of any significance has been detected when ^{4}He is produced. Again, this only means that the helium producing reaction is not caused by "hot" fusion.

Miles *et al.*[48] culminated an extensive investigation sponsored by the U.S. Navy with the results shown in Figure 7. A similar but independent study was reported by Bush and Lagowski[53] which shows excellent agreement. Gas evolving

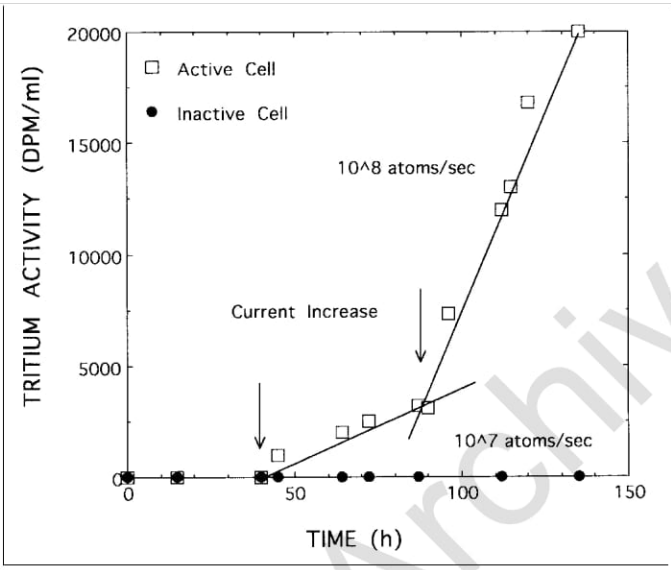

Figure 5. Tritium produced in an active electrolytic cell compared to an inactive cell in series. Changes in applied current caused changes in the tritium production rate within the active cell. This figure shows only the first part of an extended study. DPM is decompositions per minute of tritium nuclei within 1 ml of solution using the scintillation detection method.

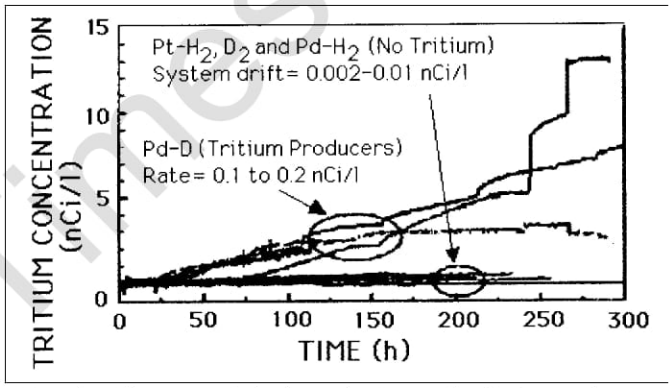

Figure 6. Tritium concentration in gas flowing over the discharge region as a function of time Active cells show a tritium increase immediately after the discharge is started, at 25 hr., while inactive samples show essentially no production. The production rates for the various samples were changed by changing the discharge conditions.

from energy-producing cells was collected in metal flasks and analyzed by a sensitive mass spectrometer. Samples producing no detectable heat produced no detectable helium, except when a leak was evident. Alloys of Ce-Pd produced detectable heat without helium being found in the evolving gas. Although the errors are large, a consistent pattern is apparent. The production rate is about a factor of 2 lower than expected if the helium were produced by a fusion reaction. This difference might be caused by helium being retained by the palladium. Presence of any helium at all in the surrounding gas implies that a significant number of the helium producing reactions occur within a few microns of the surface. Helium formed deeper within the structure is known to be completely retained by the metal. Helium production by the reaction sequence $d + {}^{10}B \Rightarrow {}^4He + {}^8Be$ followed by ${}^8Be \Rightarrow 2\ {}^4He$ would seem to be ruled out by the consistent behavior of the boron-containing sample.

II. 2.2.3 Neutron Emission

Over 300 studies have attempted to find neutrons, most with no success at all. A few careful and lucky studies have demonstrated neutron emission and determined their energy. Takahashi[54] was one of the first and the most successful. Figure 8 shows the gross emission rate while a cell was making excess energy. An energy spectrum was obtained using a NE-213

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detector with pulse-height analysis. The upper figure shows both signal and background while the lower figure gives the difference between these two values. Energies near 2.45 MeV, 4.5 MeV, and 7 MeV are evident. Other studies have reported similar energy values and emission rates. Although this work was able to correlate excess energy production with neutron emission, many studies have failed to detect neutrons when excess energy was being produced. Part of this failure may be caused by inadequate sensitivity and part may result from an absence of neutrons. It is possible that neutron emission and heat result from different reactions so their occasional synchronicity may be coincidence. Many questions still remain unanswered.

II. 2.2.4 Transmutation Products

Recent studies have revealed a variety of elements that seem to result from fragmentation of a heavy nucleus or its fusion with deuterium or hydrogen. Sometimes fusion seems to proceed fission and sometimes elements other than palladium and nickel are involved. Many claims can be cited but, for the purpose of this review, only two will be examined. The *Journal of New Energy*[55] Fall 1996, and *Infinite Energy*, Vol. 3, #13/14, 1997,[56] contain many papers claiming to have produced anomalous transmutation. A number of organizations[57] are proposing to use this effect to quickly convert radioactive isotopes to stable ones. These claims are still uncertain and are being actively pursued using a variety of methods and chemical environments.

Miley (Univ. of Illinois, U.S.)[58] and Patterson (CETI) have collaborated to examined thin coatings of mainly nickel on plastic beads after they were electrolyzed in a flowing electrolyte of Li_2SO_4 and H_2O. Great care was taken to analyze the material before hand and to remove possible contaminates from the electrolyte. Significant quantities of Fe, Ag, Cu, Mg, and Cr were detected using neutron activation analysis (NAA), energy dispersive X-ray (EDX), Auger electron spectrometry (AES) and secondary ion mass spectrometry (SIMS). Many other elements were also found but at lower concentrations. When the concentrations are plotted as a function of atomic number, four regions of enhanced concentration are produced with peaks at 15, 30, 50 and 80 au. Many of the minor elements probably result from the expected localization of impurities. However, the major elements are at such high concentrations, making this explanation difficult to support. The main anomalous elements are noted in the Periodic Table shown as Figure 9. Many of the detected elements show an abnormal isotopic ratio and have a higher concentration within the Ni layer in contrast to being found on the surface as would be expected if they plated out of the electrolyte. While most questions about the analytical methods have been answered, the nature of the nuclear process is still very much in doubt. The main problems involve how elements much heavier than Ni are produced, how the neutron/proton ratio between the proposed reactants and products can be balanced, and why the measured energy production is so small compared to the amount of nuclear transformation. Of course, the basic question remains as to how such reactions can occur in the first place.

Mizuno *et al.*[59] (Hokkaido Univ., Japan) subjected palladium to electrolysis at high pressure and high temperature. The electrodes were analyzed using EDX, AES and SIMS. Although this study is not as complete as the one described above, many of the same elements were found with abnormal concentrations and isotopic ratios. Surprisingly, significant excess Xenon was detected within the palladium metal using SIMS. Changes in the ^{104}Pd and ^{110}Pd isotopic ratio were also seen as a function of depth with the largest deviations from natural abundance at

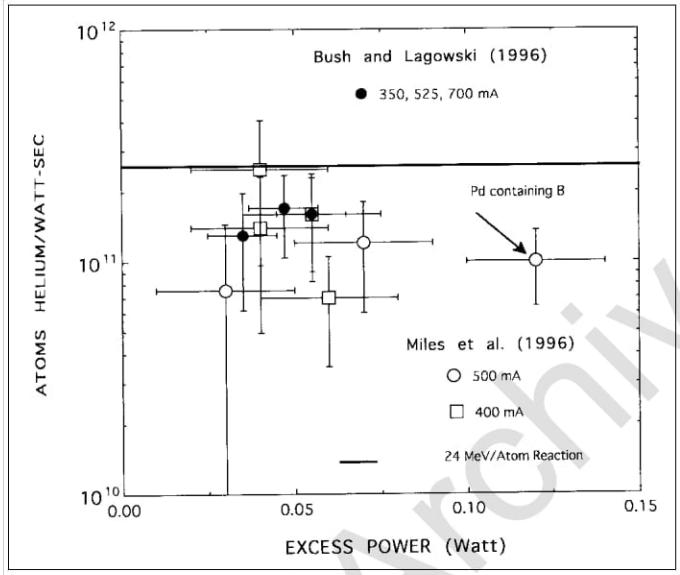

Figure 7. The number of atoms of ^{4}He collected in a flask while the cell was being electrolyzed using the indicated currents. One sample contained 500 ppm boron and gave the same result as the other samples containing less than 10 ppm boron.

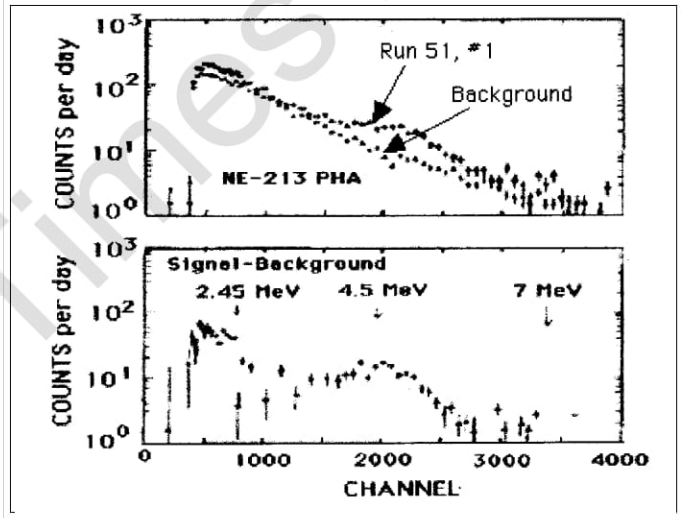

Figure 8. The upper figure shows the average counting rate for a cell during energy production and the background. The lower figure is the difference between the signal and background with the corresponding energy indicated. The count rate fluctuated during the 270 hrs of data acquisition.

the surface. Abnormal isotopic ratios resulting from formation of metal hydride molecules, which distort SIMS measurements, or because of isotopic separation caused by electromigration may occur but are difficult to justify in all cases.

II. 3.1 Gas Reaction

Arata and Zhang (Osaka Univ., Japan) explored energy production when finely divided palladium was exposed to high-pressure D_2 gas. In their case, the gas was produced by electrolyzing a palladium tube containing powdered palladium (palladium-black) in a mixture of LiOH and D_2O. Heat was seen after a delay of many days and after the internal pressure had risen to as high as 800 atm. Power levels between 10 and 20 watts were measured using flow calorimetry. Samples maintained this power for months and excess power could be re-established after the samples had been stored for over a year. Helium-4 and now ^{3}He have been extracted from energy-producing samples by heating them to 1200° C. The surrounding gas has not yet been analyzed. Because the work has been done with great care, interest in the results is growing. Several

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attempts in Japan to duplicate the results have failed because, according to Prof. Arata, the proper protocols were not followed. Additional efforts are underway in the U.S.

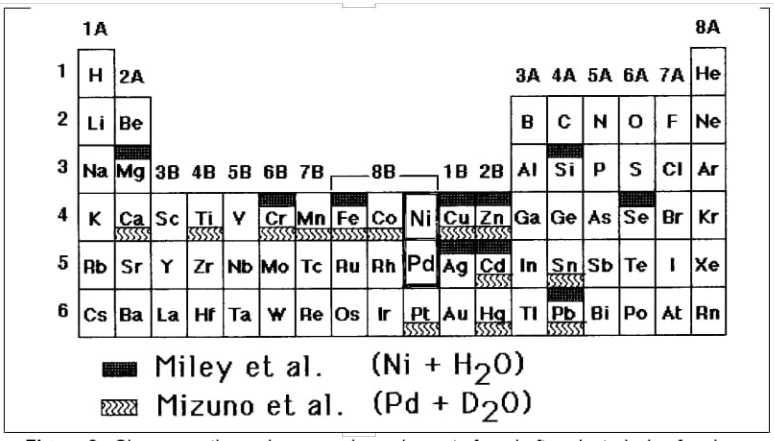

Figure 9. Shown are the major anomalous elements found after electrolysis of various systems as indicated.

II. 3.2 Electric Discharge

Dufour and co-workers[60] (Shell/CNAM, France) initiate anomalous effects by producing a silent AC discharge through an insulator surrounding a cell containing hydrogen (deuterium) gas and a metal electrode. This method involves a so-called "Ozoniser." The voltages are not sufficient to cause conventional nuclear reactions. Unusual effects have been seen including excess power production up to 10 W for H_2 and 14 W for D_2, significant loss of hydrogen isotopes from the cell, emission of ionizing radiation for days after the discharge is stopped, and increased concentration of lithium. The results depend on the nature of the electrode and the gas.

A group[61] at "Luch" (Scientific Industrial Association, Russian Federation) pioneered and continues to study a technique involving high voltage-pulsed discharge in low-pressure deuterium or hydrogen. Excess energy, various radiations, and transmutation products have been reported. The amounts and types of anomalous products depend on the amount of applied current, the metal used as the cathode, and whether H_2 or D_2 is used. The combination of D_2 with one special palladium sample produced 21 W of excess power when 95 mA was applied with a nearly linear relationship between heat and applied current. Other palladium cathodes were not as productive. Various stable elements were found in the cathode surface after excess energy was seen including Na, Mg, Ti, Fe, Ni, Cu, Rb, Zr, Nb, Rh and Ag, some with abnormal isotopic ratios. Silver was also found to produce excess power of 9 W at 51 mA when bombarded with deuterium ions. Normal hydrogen produced excess power when nickel or niobium cathodes were used but the number of transmutation products was reduced. Minor amounts of neutron and gamma emission have been detected, sometimes continuing after the current was stopped. Efforts to duplicate the results at the Naval Research Laboratory (NRL, U.S.) were only marginally successful, possibly because the method was not completely duplicated and the same palladium was not used.

Prelas *et al.* (Univ. Missouri, U.S.)[62] used a microwave heated deuterium plasma to bombard palladium with ions having bulk temperatures between 0.5 and 10 eV. They detected a significant increase in neutron and gamma emission only when the sample was being bombarded. In one case, a broad gamma peak at 8.11 MeV was seen. The results were sensitive to the type of palladium used and its temperature. Higher energies near 11 kV were used by workers in China.[63] X-ray emission near 27 keV was routinely observed when various metals were bombarded with deuterium or hydrogen ions.

II. 3.3 Proton Conduction Through Semiconductors

When certain semiconductors are heated in deuterium and a voltage is applied across their thickness, a small current can be made to flow, caused by dissolved hydrogen ions moving within the structure. Biberian (Faculté des Sci. de Luminy, France)[64] applied this technique to $AlLaO_3$ while Mizuno *et al.* (Hokkaido Univ., Japan)[65] used $Sr(Ce,Nb,Y)O_3$. Both studies observed significant excess energy production. Oriani (Univ. of Minnesota, U.S.)[30] succeeded in duplicating the results of Mizuno using a high-temperature Seebeck-type calorimeter. Although the amount of excess energy is small, it represents a large increase over the amount being applied. Oriani measured some excess even after the applied current was turned off. Another duplication using $SrCeO_3$ and $BaCeO_3$ ceramics was done in Russia[66] but the description lacks much needed detail. In this case, occasional excess energy was measured as well as neutron emission during thermal cycling. The behavior depended on the chemical purity and structure of the ceramic, an experience shared by the other studies.

II. 3.4 Rapid Decomposition of a Hydride

Yamaguchi and Nishioka (NTT, Japan)[67] first showed charged particle emission when palladium containing deuterium is rapidly heated in vacuum. Alpha particles with an energy of 4.5-6 MeV and protons with an energy of 3 MeV were detected. The samples were palladium coated on one side with MnO_x and the other with gold. Iwamura *et al.* (Mitsubishi, Japan)[68] used palladium coated with gold or aluminum and detected neutron (5σ) and tritium production in a few samples. However, extensive efforts to reproduce this work in Japan were unsuccessful. Recently, Lipson *et al.* (Russian Academy of Sciences, Russia)[69] detected neutron and gamma emission when palladium, coated on one side with a complex oxycarbide (based on an unpublished method of application) and the other with gold, was heated in air or oxygen. They report seeing 100-500 neutrons/sec-cm^2 and gamma ray peaks at 2.22 MeV, 3.8 MeV, and 6.3 MeV as well as excess energy over that expected from the D_2-O_2 reaction. Attempts to duplicate this work are presently underway. Unfortunately, the nature of the palladium, once again, plays a major role in producing the effects. In addition, the presence of other chemical environments, applied as layers, creates additional regions for abnormal nuclear reactions to occur, thereby creating additional variables.

II. 3.5 Cavitation Involving Bubble Formation

Stringham and George (E-Quest, U.S.)[70] have been perfecting a method based on generating bubbles in D_2O using an intense acoustic field. When these bubbles collapse against a metal surface, they inject deuterium and oxygen ions into the metal as a high-temperature plasma. The deuterium diffuses away from the surface while the oxygen remains trapped and forms a colored oxide. Anomalous behavior is immediate. Silver and palladium are especially good producers of anomalous energy, helium, and various transmutation products. The fact that many other metals produce no unusual results indicates absence of reactions associated with sonoluminescence within the bubbles. Unfortunately, details of the process and the results are not available to the public although a general description can be found in *Infinite Energy* magazine.[71] This is one of the few methods having high reproducibility and producing significant amounts of energy and nuclear products. People interested in the method can obtain more information by

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contacting the inventors.

A related approach has been developed by Griggs.[72] In this case, bubbles are generated by a perforated rotor which is rotated within normal water by a powerful motor. Steam is produced and the bubbles collapse against aluminum and steel. Several independent tests of the method have all found more energy produced by the device than used to rotate the rotor. Nevertheless, the company sells the units only as a way to obtain efficient, maintenance-free energy conversion.

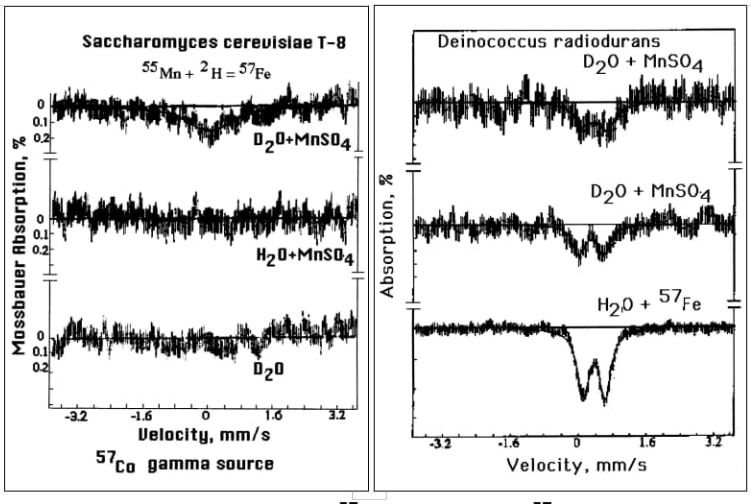

Figure 10. Mössbauer spectrum of ^{57}Fe detection using a ^{57}Co gamma emitter.

II. 3.6 Biological System

Beginning in 1954, Kervran[73] was the first to make a systematic study of nuclear reactions in biological systems using experiences by farmers and biologists. A modern study claiming transmutation was made in Japan using various cultures[74] and conventional analytical techniques. A recent study done in Russia[75] has added powerful support to the accumulating evidence. In this case, fusion between ^{55}Mn and deuterium to give ^{57}Fe in various yeast and bacteria cultures was demonstrated using the Mössbauer effect. The relative velocity between a ^{57}Co gamma emitter and the solution was changed until the gamma energy matched that required for absorption by any ^{57}Fe nucleus present. The result for yeast and bacteria cultures can be seen in Figure 10. The ^{57}Fe is produced only when Mn and D are both present in the culture and at a rate of $(1.9\pm0.5) \times 10^{-8}$ ^{57}Fe per sec per ^{55}Mn. A double hump in the spectra occurred for the bacteria culture whether the ^{57}Fe was made in or added to the culture. Apparently, ^{57}Fe made by a nuclear reaction and ^{57}Fe added to the culture both occupy the same chemical environment, but an environment that is different from the one in the yeast culture. This study is particularly persuasive because it uses a conventional method which is only sensitive to the presence of ^{57}Fe, an isotope easily excluded from the environment. Therefore, strong evidence exists for at least one nuclear reaction. What other reactions are possible?

III. THEORY

Well over 100 explanations of CANR have been attempted, most of which have little relationship to reality or to being useful. However, several models do seem to offer important, partial insights into possible processes. Many of these models have continued to be changed and improved over the years. Unfortunately, most theories address the nuclear process while ignoring the unique environment in which such reactions must occur. In addition, most models still conflict with some observations within the field or rest on assumptions not supported by observations made outside the field.

Because the nuclear events occur in a variable number of random sites within the bulk material, a quantitative relationship between theory and observation is not yet possible even though some attempts have been made. No theory has explained why only these rare sites are active or has predicted their chemical characteristics except in general terms. Confusion still swarms around the nature of the nuclear reactions. Is the detected helium produced by d-d fusion or does it result from alpha decay of destabilized heavy nuclei? Can mass be added to heavy elements by fusion between multiple hydrogen (deuterium) nuclei or are heavier nuclei involved? Why do some nuclear processes produce detectable energy while others produce none? How many theories will it take to finally understand all observations?

A few examples are summarized below to give a partial insight into the approaches being explored. It is still very risky, and likely to raise the emotional temperature in some quarters to suggest which of these ideas might be right or wrong. Therefore, neither the choice of examples nor their sequence represent a judgement of value. Courageous evaluations of several theories have been provided by Chechin[76] and Preparata.[77]

Chubb and Chubb (OIC, U.S.)[78]

This model uses ion band state theory involving stationary, three dimensional Bloch states to explain the fusion process. Thus, a few deuterium nuclei are thought to act as a wave when the deuterium concentration has achieved a critical value and when other conditions are present. These waves have a period equal to the distance between the deuterium lattice positions, thereby reducing coulombic repulsion. Occasionally, fusion occurs in small steps during D^+-D^+ wave overlap, thereby producing a helium nucleus having gradually increasing stability. The resulting nuclear energy is coupled to the lattice by a coherent process involving transfer of energy in small packets to the Fermi levels from which it is dissipated throughout the lattice. The theory predicts that a critical crystal size is required and that ^4He is the only nuclear product without gamma or any other radiation being emitted. However, the proposed particle-wave transition has yet to be demonstrated to occur in a crystal lattice.

Preparata (INFN, Italy)[79]

Using an approach called QED (Quantum Electro Dynamics), the model proposes that various coherent plasma fields exist in a crystal structure, *i.e.* the fields act like electron lasers which are completely contained within the structure. These fields are proposed to combine and provide sufficient screening of deuterium nuclei to allow fusion and other reactions to take place. The model requires the fusion process to occur at tetrahedral sites within β-PdD when the deuterium concentration has reached very high values. Released energy is absorbed by the coherent fields which then emit X-rays. However, no evidence exists for tetrahedral occupancy by deuterium in β-PdD.

Bazhutov (Erzion Center, Russia)[80]

Small quantities of massive, stable hadrons left over from the Big-Bang are thought to be present in all matter. Under certain conditions, these particles can be released from their bound state and used to catalyze nuclear reactions. McKibben (LANL, U.S.)[81] has taken a similar approach by proposing the presence of fractionally charged particles. These particles can stabilize composite nuclei which act chemically like normal matter and, when destabilized, can produce energy by catalyzing various nuclear reactions. The existence of these particles has yet to be established.

Li (Tsinghua Univ., China)[82]

A very narrow energy level is proposed to exist in the nucleus which is able to resonate with certain energy levels in the sur-

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rounding atomic lattice. The process is proposed to promote barrier penetration and nuclear interaction. The presence of this narrow level or its relationship to nuclear stability has not been established.

Hagelstein (MIT, U.S.)[83]

He has abandoned the virtual neutron model and replaced it by one involving energy transfer from a phonon laser or strong resonance vibrations operating within the lattice. Vibrations of individual atoms caused by their temperature combine to produce pockets of higher energy (temperature). Energy is accumulated in the phonon bands by nonlinear frequency shifting involving fluctuations in the phonon spectrum. This enhanced energy is transferred to a few atoms by the usual vibrational processes causing adjacent nuclei to approach each other with sufficient energy to allow various nuclear interactions including fusion and transmutation. The "Lattice Quake" model of Arata (Univ. Osaka)[84] uses similar features to explain a fusion reaction. Kucherov (ENECO, U.S.)[85] has employed phonons to propose a gradual accumulation of energy directly in the energy levels of various metal nuclei. When sufficiently high, this energy is released by α emission or fission. The quantized nature of the nuclear constituents and their very high energy levels would appear to make such an incremental transfer of energy impossible.

Mills (Blacklight Power, U.S.)[86]

All isotopes of hydrogen are proposed to have fractional energy levels below those described by conventional quantum theory. Electrons can be caused to access these levels if a suitable repository for the released energy is available. Consequently, under certain conditions, energy can be released by the formation of collapsed hydrogen atoms called hydrinos. These smaller hydrogen atoms leave the system and return to their initial size and energy elsewhere in the world. Therefore, this is an energy transfer process which does not involve nuclear reactions. However, tritium can sometimes result when complete atom collapse produces a neutron which reacts with a nearby deuterium nucleus. Variations on this approach have been proposed by Dufour[87] (Shell, France) and Yi-Fang and Zheng-Rong (Yannan Univ., China).

Kozima (Shizuoka Univ., Japan)[88]

Thermal neutrons are proposed to be trapped in crystals where they can, under the proper circumstances, interact with nuclei. This is called the TNCF model (Trapped Neutron Catalyzed Fusion). The neutrons are thought to be stabilized by forming neutron Cooper pairs and by acting as Bloch waves which prevent normal neutron decay and prevent interaction with nearby nuclei until a large perturbation is suffered by the crystal. This perturbation is proposed to be caused by certain surface impurities, some of which subsequently react with the released neutrons. The approach is handicapped by the need to make several arbitrary assumptions to make the model consistent with observation. These assumptions include the need to justify why neutrons are not emitted after they become available to interact with the surrounding nuclei and why significant tritium is not formed when lithium is present.

Miley *et al.* (Univ. Illinois, U.S.)[89]

The region between two metals having large differences in Fermi electron levels is proposed to provide an environment in which the coulomb barrier can be reduced, the so-called swimming electron layer (SEL). Conduction electrons which concentrate at a metal surface, producing a characteristic work function, are thought to form a plasma of sufficient magnitude to partially shield deuterium nuclei located within an interface region. The reduced average distance between nuclei caused by this screening increases the normal fusion rate. Recent work by this group[90] applies the concept to transmutation reactions. In this context, nuclear interaction is proposed to occur at much larger distances than normally experienced for d-d fusion. The SEL is proposed to reduce the distance by an amount sufficient to cause enhanced nuclear interaction. However, anomalous nuclear reactions are seen when conditions required for the swimming electron layer to form are absent.

Kim (Purdue Univ., U.S.)[91]

This is not a general model but a more exact calculation of the magnitude for the coulomb barrier using conventional methods. The analysis concludes that barrier penetration for fusion is easier than first thought, but not as easy as is required to explain many CANR claims.

Many models propose a resonance processes but they differ in what is resonating and how the resonance structure interacts with the nucleus. Preparata sees a wave-like electron structure neutralizing the coulomb barrier while Miley proposes enhanced concentration alone can do the trick. The Chubbs visualize direct interaction of deuterium waves; Kucherov and Li would have vibrational energy of the atom-electron structure add energy directly to the nucleus thereby causing destabilization; and Hagelstein and Arata have this vibrational energy cause direct nuclear interaction between adjacent nuclei. Each model has the electron structure carry away the resulting nuclear energy which is dissipated throughout the lattice as heat.

The models proposed by Mills and Dufour, involving a change in energy and size of the hydrogen atom, are not part of CANR unless this change results in a nuclear reaction. Although most examples of heat production are not consistent with this model, occasionally results are seen which are consistent. Perhaps several mechanisms are possible depending on the imposed conditions.

IV. DISCUSSION

Separating fact from fiction is the main problem in evaluating the value of these extraordinary claims. The basis for accepting evidence for such unconventional nuclear reactions is very much in the mind of the beholder. Is the reader familiar with the technique? Are the investigators known to the reader and can they be trusted? Is the work peer reviewed by an acceptable journal? Unfortunately, most people working in this field are not known to the general physics community and most of the work is not peer reviewed. I have attempted in this review to present enough detail about some of the better work so that a reader will at least appreciate why this field is receiving increased attention. Although definite conclusions are still not possible, some general trends are apparent. Unfortunately, many studies can not be judged because so little detail has been properly described and many of the techniques have not been used by several independent investigators. On the other hand, some very good studies are available which use conventional, well accepted techniques. In addition, similar results have been obtained using a wide range of methods and techniques in laboratories throughout the world, only a small fraction of which are described in this review. While this common experience is not proof, it encourages continued open-minded interest in the field.

World-wide experience using many techniques show that the mix of nuclear products and the ability to make excess energy are both very sensitive to the nature of the chemical environment in which the reactions are thought to occur. Because few experiments use identical chemical environments, the results seem to have no clear pattern and are difficult to reproduce. Although error and incompetence add to the problem, these are

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clearly not the main variables. Accepting this insight is fundamental to accepting the claims.

Neutron production, the favorite of many physicists, does not occur at a significant level and may not be associated with heat production. Therefore, the unusual energy of the emissions can not be used with confidence to understand heat production. On the other hand, some neutron emission is detected and must be explained. Intense bursts are sometimes observed and are usually associated with changes in the chemical or physical environment. This behavior has prompted interest in the effect of crack formation, so-called fractofusion. Such an environment would be expected to produce "hot" fusion caused by the high voltages produced therein. However, the required amount of tritium is not observed when neutrons are detected.

Tritium can be produced, but only with difficulty. Although it is seldom found in cells making excess energy, its production may be accompanied by a few emitted neutrons. Dendrites on the cathode surface seem to be present when it is formed in an electrolytic cell. Intense electric fields or high voltage discharge encourage its formation even though the voltages are lower than conventional theory would require.

Helium or a few transmutation products are present after excess energy is detected. The mix between these products depends on the raw materials present. Deuterium produces helium, while light hydrogen produces various transmutation products involving at least the alkali metals. Helium-3[42] may be produced when both H and D are present in sufficient concentrations. Some of the helium is produced with sufficient energy and sufficiently close to the surface to be identified as alpha particles.

More complex reactions giving a spectrum of products seem to be possible. Various fragments of nickel or palladium have been detected, some with abnormal isotopic ratios. Occasionally, short-lived radioactive isotopes are detected. More difficult to justify are the heavy elements which can only result from multiple addition of hydrogen nuclei or other light elements to palladium or nickel. These new claims are still being debated and offer a significant challenge to any theory. Particularly troublesome are the lack of resolution in the neutron/proton ratio between the apparent reactants and products, and the lack of corresponding energy production.

X-rays are occasionally detected using various methods. However, the emissions are sporadic; they do not act like bremsstrahlung nor can they always be identified as characteristic X-rays. An intriguing observation is reported by Rout *et al.* (Bhabha Atomic Research Center, India).[92] Every palladium sample, after being loaded with either deuterium or hydrogen, produced an emission which is influenced by electric and magnetic fields, able to pass through certain thin absorbers, and able to produce fogging of X-ray film. Presence of oxygen enhanced the effect. A very complete study rules out conventional types of radiation or chemical products. The source of this radiation as well as X-rays detected in other studies is still uncertain. However, these observations continue to be consistent with early studies and continue to support the initial conclusion that the nuclear energy is somehow dissipated throughout the atomic lattice rather than at the site of its production.

Gamma emission is occasionally seen sometimes with a measurable half-life after the experiment is stopped. However, no study has observed gamma emission having a consistent intensity or energy. Once again, the behavior apparently depends on the nature of the chemical environment.

Everyone can agree that a nuclear reaction involving coulomb barrier penetration does not occur within ordinary matter at any significant rate. The problem remains as to whether it can occur at all in some rare and unusual environments. Experience shows that a few materials have the capacity to contain these environments, *i.e.* to produce anomalous effects. This selectivity not only demonstrates absence of random error but also suggests the existence of a universal nuclear-electron interaction, albeit negligeable in most cases. Once a nuclear-active material is formed, a wide spectrum of nuclear reactions appear to be possible within the same sample. How is this possible? How is the choice made as to which reaction will occur? A logical possibility involves inhomogeneities within the material in which one reaction takes place while other isolated regions cause a different reaction. This is consistent with the common observation of anomalous elements occupying isolated regions, generally near the surface. If this conclusion is correct, we are faced with the possibility that, once a nuclear-active material is produced, minor variations can have a large effect on the type of nuclear reaction produced. Understanding the nature of these isolated regions is fundamental to making this phenomenon occur at high levels and with predictability. Such knowledge is also basic to any successful theory.

V. CONCLUSIONS

I can sympathize with anyone struggling with the reality of and meaning behind these disparate observations. Because skepticism is so wide spread, an intense effort by skilled and well funded scientists required to answer many of the questions has not been applied to the problem. The need for proof to be "compelling," as many scientists require, adds to the difficulty. Nevertheless, I suggest sufficient information is now available to strongly support claims for certain nuclear reactions taking place under conditions not sanctioned by conventional theory.

The human race is desperate to find energy sources which are pollution-free and renewable. In addition, we have the serious problem of disposing of radioactivity from fission reactors and the nuclear arms race. The CANR phenomenon may offer a solution to both problems. I suggest that lack of certainty about its reality or a lack of knowledge about many of the details should be viewed as temporary distractions and not used as justifications for ignoring the potential benefits. Even if many of the claims have trivial explanations, the evidence overwhelmingly indicates the existence of a novel phenomenon having unexplored benefits. Why not test the possibilities no matter how remote they seem?

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TO THE FRIENDS OF "COLD FUSION"

I have been involved with the "cold fusion" field since its inception in 1989, first at the Los Alamos National Laboratory and, upon retiring, at my own laboratory. This effort has resulted in seven papers[1-7] describing experimental work as well as eight reviews.[8-15] This article is my final effort.

From this vantage point, I would like to make several comments about the status of the field. Clearly, a new phenomenon having significant importance to science and technology has been discovered. Unfortunately, over the years, skepticism toward this conclusion has solidified so that now even very well done studies showing support for the idea can no longer be published in conventional journals. One of many examples is the above review which was rejected by four reviewers when it was submitted recently to the *International Journal of Modern Physics.* You can judge for yourself whether the article deserved such treatment. Other authors have had similar experiences. This strong negative attitude has been growing because most efforts by established scientists to achieve reproducibility have failed. Indeed, it has been said that the better the study, the less dramatic the results. This conclusion makes a lot of sense to someone who rejected the claims in the first place. However, the problems of reproducibility can be explained just as well in another way.

One consistent pattern has been found in all studies. Production of the "cold fusion" effect depends on the nature of the material in which the effect is claimed to occur. This unusual nature is very difficult to achieve. Apparently, when it is achieved, unusual nuclear reactions occur with each attempt. One of the nuclear-active materials which has been studied in sufficient detail to show this correlation is palladium. It is now possible to identify palladium which has the potential to produce the Pons-Fleischmann Effect with a high degree of certainty. Unfortunately, this information has come too late to alter the present skeptical attitude. Had such insight been available earlier, we could have demonstrated reproducibility by now and general support for the field would be available. Failure to study the material properties which influence reproducibility has been a major mistake.

This error has resulted because too much of the limited funding was used to demonstrate the effect in a manner that would satisfy a skeptical physicist especially one who required a pattern consistent with "hot" fusion. In addition, the few material studies that were undertaken emphasized the effect of external processes such as annealing temperature or surface treatment. The basic nature of the material was largely ignored. To make matters worse, people who had such knowledge about palladium, such as Johnson-Matthey together with Drs. Pons and Fleischmann, did not share the important details with other people working in the field. The irony is that this knowledge, which was protected for legal and financial reasons, is now worthless. The general success it might have encouraged is no longer possible because the large amount of funding available a few years ago is now exhausted. With it has gone the willingness of conventional science to give the field the benefit of doubt.

Fortunately, all is not lost. Small studies, generally by individuals using their own money, are still ongoing and are producing some impressive results - at least to someone who is in a position to learn the details. Gradually, one or more of these efforts will produce effects of such magnitude that they can not be ignored. Meanwhile, the rest of us will have to wait patiently for this success to attract general interest before funding will again be available.

Sincerely,
Edmund Storms

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HANS COLER'S FREE ENERGY GENERATORS

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Immediately after World War II, Allied technical teams plundered all the scientific data they could find in Germany. Much of what they learned remains classified to this day. One most remarkable exception to this secrecy is the declassified British Intelligence Objectives Subcommittee (BIOS) Final Report #1043, Item #32: "The Invention of Hans Coler Relating to an Alleged New Source of Power." Coler was interviewed by R. Hurst (Ministry of Supply) and Capt. R. Sandberg (Norwegian Army):

> [Naval Captain] Hans Coler is the inventor of two devices by which it is alleged that electric energy may be derived without a chemical or mechanical source of power. Since an official interest was taken in his inventions by the German Admiralty it was felt that an investigation was warranted, although normally it would be considered that such a claim could only be fraudulent... Accordingly, Coler was visited and interrogated. He proved to be cooperative and willing to discuss all details of his devices, and consented to build and put into operation a small model of the so-called Magnetstromapparat [Magnet Current Apparatus]... With this device, consisting only of permanent magnets, copper coils and condensers in a static arrangement, he showed that he could obtain a tension of 450 mv for several hours... One model is said to have worked for three months locked in a room in the Norwegian Legation in Berlin in 1933... The greatest tension obtained was 12 volts.

Coler also invented another device called the "Stromzeuger" (Current Generator). He claimed that "with an input of a few watts from a dry battery an output of 6 kW could be obtained indefinitely." The last and largest model which Coler built was destroyed by a bomb in 1945, but "Coler expressed his willingness to construct it, given the materials, the time required being about three weeks." The public version of the BIOS report does not state whether or not this was done. However, Bill Lehr (d. 1996) informed this writer that a close friend of his once saw a Stromzeuger in operation in the offices of MI5 in London, and a copy of the original BIOS report which was over 200 pages in length. The declassified report is a mere 30 pages long.

Hurst and Sandberg also interviewed Dr. F. Modersohn, who had been collaborating with Coler and financed his research for ten years; he corroborated every detail of Coler's story. The Magnetstromapparat was developed by Coler and von Unruh (who had died by 1945), and they were assisted by Franz Haid of Siemens-Schukert. Haid also built a working model which was seen in operation by Dr. Kurt Mie (Berlin Technische Hochschule) and Herr Fehr, who was the assistant of the renowned scientist Fritz Haber. The Magnetstromapparat was described thus:

> This device consists of six permanent magnets wound in a special way so that the circuit includes the magnet itself as well as the winding (Figure 1). These 6 magnet-coils are arranged in a hexagon and connected as shown in the diagram (Figures 2 and 3), in a circuit which includes two small condensers, a switch, and a pair of solenoid coils, one sliding inside the other. To bring the device into operation the switch is left open, the magnets are moved slightly apart, and the sliding coil set into various positions, with a wait of several minutes between adjustments. The magnets are then separated still further, and the coils moved again. This process is repeated until at a critical separation an indication appears on the voltmeter. The switch is now closed, and the procedure continued more slowly. The tension then builds up gradually to a maximum, and should then remain indefinitely. The greatest tension obtained was stated to be 12 volts...

In our presence…Coler built an apparatus as shown in Figures 1-3. *It is to be noted that some of the magnets are wound in a clockwise direction looking at the N pole (called left) and others in an anti-clockwise direction (called right).* The magnets were selected to be as nearly equal in strength as possible, and the resistance of the magnet-coil combination was checked after winding to see that this also was uniform (about *0.33 ohm*)...The physical arrangement was as shown in Fig. 2…A mechanical arrangement of sliders and cranks for separating the magnets evenly all around was made up…

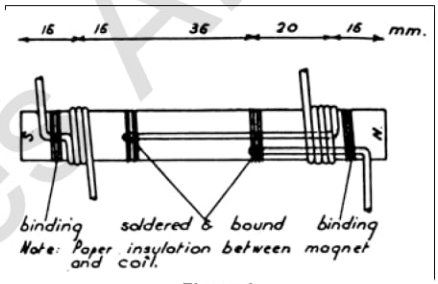

Figure 1.

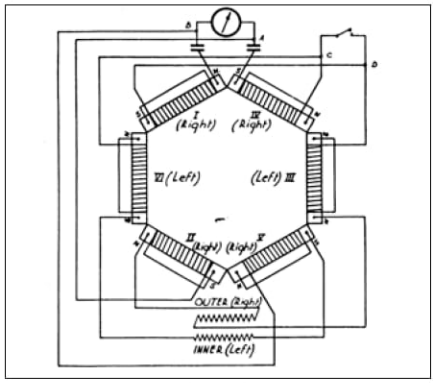

Figure 2.

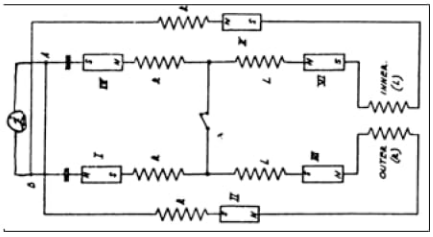

Figure 3.

When the magnets were at a separation of about 7 mm, the first small deflection was noted. The switch was closed and by slow adjustment of the sliding coil, and by increasing the separation of the magnets to just over 8 mm, the tension was raised to 250 millivolts. This was maintained for another 3 hours when a soldered tag became disconnected, and the meter slowly dropped back to zero. Soldering up the broken connection did *not* restore the tension. The magnets were closed up and left overnight, and the same procedure for adjustment was repeated on 2-7-46. After about 3 hours a deflection of 60 millivolts was obtained; this was maintained for more

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than 30 minutes, but then decreased to zero when further adjustments were tried.

During all this work the model was completely open, and nothing could be hidden in it. The breadboard and meter could be picked up and moved round the room, tilted, or turned, without effect.

The apparatus would appear to be to crude to act as a receiver of broadcast energy, or to operate by induction from the mains (the nearest cable was 6 feet away), and the result must for the moment be regarded as inexplicable…

[Coler was of the opinion that] ferro-magnetism was an oscillating phenomenon, of frequency about *180 kilohertz*. This oscillation took place in the magnetic circuit of the apparatus, and induced in the electrical circuit the frequency which of course depended on the value of the components used. These two phenomena interacted, and gradually built up the tension... Coler stated that the strength of the magnets did *not* decrease during the use of the apparatus, and suggested that he was tapping a new sort of energy hitherto unknown "Raumenergie" (Space-energy).

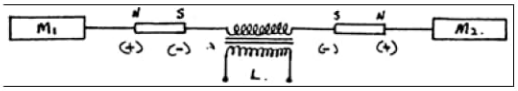

Figure 4.

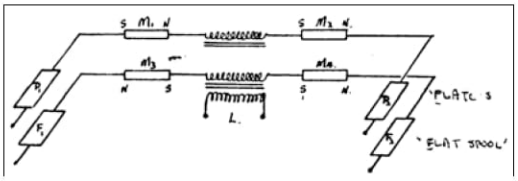

Figure 5.

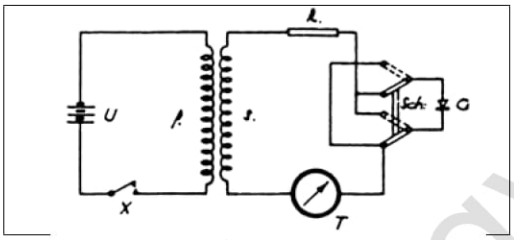

Figure 6.

It was judged that Coler was an honest experimenter and not a fraud... The result obtained was genuine insofar as could be tested with the facilities available, but no attempt has yet been made to find an explanation of the phenomenon…

The Stromzeuger was invented in 1925, at which time Coler showed a 10-watt model to Prof. Kloss in Berlin. Kloss tried to interest the German government in the invention, but his request was refused (as was Coler's patent application) because it was a "perpetual motion machine." The model was also seen by Prof. Schumann (of terrestial resonance fame), Prof. Bragstad (Trondheim), and Prof. Knudsen (Copenhagen). Kloss and Schumann wrote reports explaining the physics of its operation, which apparently amplified the Barkhausen Effect to a useful level. The Stromzeuger was described in the BIOS report as follows:

> This device consists of an arrangement of magnets, flat coils, and copper plates, with a primary circuit energized by a small dry battery. The output from the secondary was used to light a bank of lamps and was claimed to be many times the original input, and to continue indefinitely...

Coler and von Unruh constructed a 70 watt model of the Stromzeuger in 1933 and demonstrated it to Dr. F. Modersohn, who subsequently financed the development of the invention and established the Coler Gmbh for the purpose. In 1937, Coler built a 6 KW version of the Stromzeuger. In 1942, Modersohn demonstrated the device to the Research Department of the German Navy, which intervened and supplied them with materials, meters and tools. Thereafter the research was directed by Oberbaurat (Naval Construction Chief) Seysen, who assigned Dr. H. Frolich to assist Coler for several months. The operation of the newly developed apparatus turned out to be more complicated than they had first thought, but progress was made. The large Stromzeuger was destroyed by a bomb which struck Coler's house in Kolberg (Pomerania) in 1945. Coler had been powering his house with the unit for three years.

Hurst and Sandberg gave a summary account of the Stromzeuger in their report:

> The basic principle is that *an electron is to be regarded not only as a negatively charged particle but also as a South magnetic pole.*
>
> The basic element is that of an open secondary circuit, capacity loaded, inductively coupled to a primary circuit. The novel feature is that the capacities are connected to the secondary core *through permanent magnets*, as shown in Figure 4.
>
> It is claimed that, on switching on the primary circuit, "separation of charges" takes place, *i.e.*, Magnet 1 becomes positively charged and Magnet 2 becomes negatively charged, and that these charges are "magnetically polarized" when they are formed, owing to the presence of the magnets. On switching off the primary circuit a "reversing current" flows in the secondary, but the magnets "do not exert a polarizing effect on this reversal."
>
> Two of these basic elements are now placed together making a double system or stage with the plates close together in parallel planes as shown in Figure 5. The secondary windings are both exactly equal and wound in a direction such that on switching on the primary coil the electrons in the secondary coil flow from P_1 to P_2 [P = Plate] and F_1 to F_2 [F = "Flat Spool"].
>
> It is then stated that system F_1-F_2 merely has an inducing effect, and the useful current comes into existence in the system P_1-P_2.
>
> A single stage cannot be effective but two stages connected so that the numbers of effective North and South poles are equal will provide a basic working arrangement. More double stages can then be added to provide higher outputs.
>
> It is then stated that as well as the normal electrons flowing from the battery and from induction when the circuit is opened or closed, "space electron" flow from "repelling spaces" to "attracting spaces" between the plates…

Profs. M. Kloss and R. Franke (Technical College of Berlin) tested the Stromzeuger in March 1926; their report was included in BIOS Report 1043:

> The apparatus…consists of: a double row system of copper plates, a double-row system of flat spools, and a system of electromagnets, to whose cores silver wires are attached and through which branch currents of the plate-system are conducted. For each of the three systems a 3-part accumulator battery of 6 volts/6.5 ampere-hours capacity is provided. The plate-circuit and the spool circuit are parallel so that the two batteries appertaining thereto can also be replaced by a single battery. This was ascertained… by switching off the one battery while the apparatus was working.

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When asked why two batteries were used at all, Captain Coler declared that for starting the apparatus a double battery is necessary to get a second charge-impetus after exciting with the one battery, and this for releasing the peculiar character of the apparatus. A test… confirmed this assertion in as much as the mechanism could not be started with the single battery; on the contrary, the "adjustment" of the mechanism got disturbed.

Current-indicators are built into each of the three circuits mentioned, as well as volt-meters, behind some switch resistances necessary for the "adjustment." Between the open ends of the two plate and spool-systems there are the terminal clamps for the effective circuit for whose loading 3 bulbs of 8 volts are provided. The apparatus was then put into action and above all the load was tested with the aid of the built-in instruments, that is on being loaded with [2-3] lamps…

The consumption of energy in the external circuit is greater than the energy taken from the batteries. According to the circuit… the magnet-exciting circuit is fed by a special battery, completely separated from the other two circuits. Consequently, a direct comparison of efficiency and consumption of the apparatus would mean that only the sum of current of the plate circuit and of the spool circuit would count…

The reception of current from the two batteries in this case… was 1.7 watt while the consumption of the bulbs amounted to about 8 watt. Especially striking in this connection is the considerably higher current-power in the bulb-circuit being about 12 times bigger than the current coming from the two batteries…

Prof. W.O. Schumann (Munich) also tested the Stromzeuger in 1926; his six page analysis was included in an appendix of the BIOS Report:

The apparatus in question principally consists of two parallel connected spools, which being bifilarly wound in a special way, are magnetically linked together. One of these spools is composed of copper sheets (the spool is called the plate spool), the other one of a number of thin parallel connected isolated wires (called: spool winding), running parallel at small intervals to the plates. Both spools can be fed by separate batteries; at least two batteries are necessary to put the spools to work.

The spools are arranged in two halves each, according to the bifilar winding system. The batteries are attached to the starting points, and the current-receivers to the parallel connected ends. Inter-communications are connected between parallel windings of the two halves of the plate spool which contain iron rods with silver connections. These rods are magnetized by a special battery through applied windings (called: exciter windings).

According to the statement of the inventor, the production of energy principally takes place in these iron rods, and the winding of the spools plays an important part in it… (The form of the spool is a long small rectangle).

The inventor stated that the apparatus in its installation was very sensitive, especially with regard to the magnetic conditions of the iron cores, and that a wrong treatment [internal measurements] would cause interferences which would be wearisome and very difficult to be eliminated.

The exciter winding is electrically completely separated from the other windings…

Installed in the apparatus were 3 current meters for the currents from the 3 batteries, and furthermore current and volt meters… for the current receivers. One and two bulbs respectively were employed for this purpose…

As a striking fact it should be mentioned that the spool circuit having been at first always switched on alone, received a current of 104 mA. As soon as plates and exciter circuit additionally and simultaneously were turned on, as, according to the inventor, the apparatus demands it, the current in the spool circuit comes down to about 27 mA…

After the present examination, carried through as carefully as [possible], I must surmise that we have to face the exploitation of a new source of energy whose further developments can be of an immense importance… I believe that a further development of the apparatus… will prove justified and of great importance.

In 1943, Hans Coler and Dr. Heinz Frohlich made a report to the Research Department of the Admiralty (OKM) in Berlin, in which they described the Stromzeuger:

The apparatus consists of three principle circuits which are inter-wound and inter-coupled in a peculiar way. Some of these are divided again into single subsidiary circuits which evidently have all to be brought into resonance with one another.

The principal circuits (called the anchor) in which the energy gain probably occurs, consists of metal plates between which transformer coils are connected, the whole being connected to one large coil plate. On each of the single windings on this is coupled a large flat coil (called field). These flat coils are interwound in two groups; these groups represent the turns of a transformer. This couples, on one hand on the flat coils of the other group (as secondary coils), and on the other hand on the anchor-plate coil, which is placed between them. The third electrically independent circuit (called the directing circuit) regulates this transference. Figure 1 [not included in the BIOS Report] shows diagramatically and in plan these interwound parts. Figure 2, the so-called basic diagram, shows the connections between these different parts. This basic diagram shows the conditions necessary for self-interruption. In consequence of this arrangement, different types of currents are created in different conductors (pulsed DC, AC, etc.).

The transformer coils, connected between the anchor plates, are connected in a peculiar way through thin permanent magnet rods. Their main object seems to be to pre-magnetize the transformer cores; it is, however, very probable that they are also connected with the Barkhausen Effect…

In his report Coler also described the following simple, significant experiment:

Given a solenoid consisting of two windings, one upon the other, of the same length and number of turns, enclosing a soft iron cylindrical core. Firmly attached to one end of the core is a pre-magnetized steel rod. If an alternating current is passed through one of these coils, acting as primary, the residual magnetism of the steel rod is strengthened during one half cycle, through the magnetism induced in the core, during the other half it is weakened. If now the other winding is connected in series with the pre-magnetized steel rod (as secondary coil) in such a way that the secondary current must pass through the magnet, one half cycle of the secondary cur-

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rent must be more or less subdued; in other words, a rectifying effect must be created. It may be remembered that according to measurement by Profs. Kloss and Schumann a high-frequency pulsed direct current (about 180 kc) is flowing in the output resistance of the apparatus, for the creation of which no other explanation is possible.

Another experiment with two double-wound solenoids, connected in series, revealed that "in such a secondary circuit a considerable DC component exists which can be strengthened by means which we shall not go into here…" Experiments were conducted with the plate and flat coil unit to test their interactions:

As the plates are not only charged as condensers, but also have directed currents passing through them it had to be assumed that their mutual influences not only consisted of a condenser effect, but that they also created a magnetic field… It appeared that the "Ankertrakte" AC or BD are not all to be considered as oscillating units, but that the single group systems, consisting of plate - to anchor coils - plate, already represent independent oscillation circuits. *According to this the apparatus contained ten such oscillation circuits…* In order to make the apparatus work the harmony of all oscillating circuits in their individual frequencies would evidently be necessary (at least within certain limits determined by the suppression in question… The previous occasional success must be considered as due to chance.

The mutual influence of the flat coils upon one another could not easily be examined because, despite the great distance between the windings (25 mm), they have remarkably great apparent resistance (about 200 ohms at 10 kc).

It appeared that the power factor of both of the flat coils wound 1:1, in consequence of their peculiar interwinding have the astonishingly high value of 0.85. The value of the power factor was at a maximum at 10 kc, at which frequency the most favorable matching of the impedance… was obtained.

The repeated mention of 10 kc is also found in the scientific literature on the Barkhausen Effect. After all his experiments and measurements, Coler offered the following explanation of the way in which the apparatus works:

Due to the connecting of the batteries, a current impulse is induced in the anchor circuit which charges the plates. The discharge circuit from the plates causes electrical interruption of short duration of the battery current in the field circuit, which furthermore inductively interrupts, or changes the direction of, the battery current in the directing current for a short time. The electromagnetic field induced by this process in the directing circuit by its dissipation, induces over the field circuit a current in the anchor circuit recharging the plates, and so forth.

Due to the influence of the Barkhausen Effect each single process has an impulse-like character, and the necessary change of phase is produced to allow the regularity of the process.

Due to a source, up to the present not investigated, and not explainable by existing scientific theories, an additional quantity of energy is freed during each cycle which leads to a continual raising of the amplitude of the mutual processes, until the magnetic cores are saturated.

From the fact that in the resistance of the apparatus pulsed direct current is flowing… There is possibly an up to now unknown rectifying effect, or alternatively the gain in energy is produced only during one half of the cycle, either during the charging or discharging of the plates. The activity in the apparatus must take place *in the ten oscillation circuits in a phase-like manner…* No technical means were available to make the necessary tuning adjustments.

It is clear from the above that the success of the inventor up to now could only be due to chance, or happy accident. The necessity, therefore, arises to transfer the apparatus from the state of empirical development, with sufficient technical means and based on results of an exact basic research, to a state of working procedure which can be controlled.

Other experiments, conducted by Frohlich with the arrangement in Figure 6, convinced Coler that his theory was correct:

The result obtained with this experimental arrangement… was the clear proof of a considerably larger energy during opening (intake), compared with closing impulses… The [10-50%] difference is always in favor of the opening impulse… Consequently this observation can also be considered as a proof of the fact that an energy difference exists… [There is a] considerable, but extremely short, energy peak of the opening impulse… My development of the "Space Energy Receiver" was based on this and was successful.

In the 1980s, George Hathaway (Planetary Association for Clean Energy, PACE) constructed a Magnetstromapparat which produced 50 millivolts, and demonstrated it at unconventional technology conferences. There has been no news of further development.

The Barkhausen Effect upon which the Coler inventions work is a low-field phenomenon that occurs when a ferromagnetic material is subjected to a change in the applied magnetic field. A series of discontinuous steps develop, corresponding to reversals in magnetization domain volumes from 10^{-10} to 10^{-8} cm^3. The size of the discontinuities can be increased by stressing the magnet. Possibly the soft iron magnets which Coler used were subjected to such stress by ultrasonic magnetostriction from the coil windings at the 180 kHz resonant frequency.

One can only wonder why British Intelligence (sic) declassified the Coler report, but we can be glad they did. Would that they had seen fit to include more schematics of the Stromzeuger, because the available diagrams are woefully inadequate. At least we now know a few key facts, to wit: (1) Ferromagnetism resonates at 180 Khz; (2) The Barkhausen Effect can be amplified to provide useful power (10 Khz is another key frequency here); (3) "Some of the magnets are wound in a clockwise direction looking at the N pole (called *left*) and others in an anti-clockwise direction (called *right*)." The resistance of the magnet-coil combination was about 0.33 ohm; (4) "The basic principle is that an electron is to be regarded not only as a negatively charged particle but also as a South magnetic pole;" (5) "The novel feature is that the capacities are connected to the secondary core *through permanent magnets;*" (6) "There is a considerable, but extremely short, energy peak of the opening impulse."

It is to be hoped that the Stromzeuger can be redeveloped, since it is a relatively simple, low technology device requiring no exotic components. It should not be left "to chance, or a happy accident," as it was for Hans Coler. The BIOS Report #1043 is available from Rex Research, P.O. Box 19250, Jean NV 89019 USA for $9 postpaid ($11 overseas).

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"Negative Resistance" Discovered?

The following press release was issued in July by the State University of New York at Buffalo, Buffalo, New York:

CARBON COMPOSITES SUPERCONDUCT AT ROOM TEMPERATURE

SUPERCONDUCTION AT ROOM TEMPERATURE: NEGATIVE ELECTRICAL RESISTANCE SEEN IN CARBON COMPOSITES

LAS VEGAS—Materials engineers at the State University of New York at Buffalo have made two discoveries that have enabled carbon-fiber materials to superconduct at room temperature.

The related discoveries were so unexpected that the researchers at first thought that they were mistaken.

Led by Deborah D. L. Chung, Ph.D., UB professor of mechanical and aerospace engineering, the engineers observed negative electrical resistance in carbon-composite materials, and zero resistance when these materials were combined with others that are conventional, positive resistors.

Their observation of zero resistance is the first time that this has been seen without cooling. Zero resistance has been seen in superconducting materials, but only at temperatures of 125 degrees Kelvin, about -150 degrees Centigrade or -234 degrees Fahrenheit.

Without resistance, there is no energy loss, so the amount of energy that is put into a system is exactly the amount that it produces.

According to the researchers, the discovery has the potential to lead to much faster, far-more-efficient electronic devices, previously assumed to be possible only with the development of room-temperature superconductors. Potential applications include much-simpler, more-powerful electronic circuits in computers and far-more-efficient "smart" structural components for aircraft and concrete structures.

The research was presented here today (July 9, 1998) in a keynote address at the fifth International Conference on Composites Engineering by Chung, who holds the Niagara Mohawk Chair in Materials Research at UB.

"We have achieved zero resistance without cooling and without a superconducting material," said Chung.

"With structural electronics, the structural composite itself can act as the electrical circuitry, but the fibers in the composite are far less conductive than copper. Our research shows that it is possible to overcome that resistance and make these structural electronics far more efficient," she said.

This finding of negative resistance flies in the face of a fundamental law of physics: Opposites attract.

Chung explained that in conventional systems, the application of voltage causes electrons—which carry a negative charge—to move toward the high, or positive end, of the voltage gradient.

But in this case, the electrons move the other way, from the plus end of the voltage gradient to the minus end.

"In this case, opposites appear not to attract," said Chung. The researchers are studying how this effect could be possible.

Chung, working with Shoukai Wang, a UB doctoral candidate in mechanical and aerospace engineering, made the discovery while conducting research on the intrinsic electrical properties of carbon composites related to developing "smart materials," in which she has played a leading role.

Chung explained that it is the unusually high pressure used to cure the carbon-epoxy composite that appears to be responsible for the finding.

"We were looking at the effect of curing pressure on the junction between carbon-fiber layers, and were making electrical measurement of the interface," she said. "When we saw the negative resistance at the interface, we didn't believe it for quite a few months. But after checking and rechecking our connections, using different meters over a period of time and observing the continuous change of resistance from positive to zero and then to negative values during curing, we came to realize that what we were seeing was truly negative resistance."

According to Chung, an unknown mechanism must be at work that is being triggered by sufficient contact between the layers of carbon fibers.

In the experiments, two layers of carbon fibers oriented in different directions and bound together by epoxy, Portland cement or pressure demonstrated negative resistance as low as -8 ohms for a contact area of one square centimeter. (An ohm is a unit that measures electrical resistance.)

The researchers noted that absolute zero resistance can be achieved when the values of positive and negative resistors connected in series match exactly.

"It's a matter of tailoring them to make them exactly the same," said Chung.

A patent application has been filed on the invention. Previous patents filed by other researchers on negative resistance have been limited to very narrow ranges of the voltage gradient.

In contrast, the UB researchers have exhibited negative resistance that does not vary throughout the entire gamut of the voltage gradient.

Companies that are interested in technical information on the invention should contact the UB Office of Technology Transfer at 716-645-3811 or by e-mail at <lohrman@research.buffalo.edu>.

•• End of Press Release ••

Despite the fantastic implications of the possible discovery, the story was not widely covered in the news media—perhaps because it was immediately attacked by critics. For example, in a United Press International (UPI) wire report (July 10, 1998) by Mara Bovsun, Oak Ridge National Laboratory scientist Richard Kerchner was quoted, "Negative resistance is not possible. It makes no sense." In the same wire report, Jason Lo of the Canada Center for Minerals and Energy Technology in Ottawa was quoted: "We are still in the shock phase." It is like "instead of seeing water flowing downhill, they are seeing water flowing uphill."

In an e-mail discussion group, the often open-minded physics Nobel Laureate Brian Josephson commented on the energy implications of "negative resistance": "Even if it *were* a real effect, *e.g* extracting energy from the vacuum, it would not be superconductivity...I am left speechless! Pass!!"

The *Los Angeles Times* had prepared a story on the claim but it did NOT run in the printed paper, only on the paper's WWW site. The story by K.C. Cole on July 10th was titled: "Experts Scoff at Claim of Electricity Flowing With 'Negative Resistance.' "Encapsulating the story, Cole wrote:

"To the general disbelief of experts in the field, a University of Buffalo scientist claimed Thursday to have discovered a material that conducts electricity with 'negative resistance' at room tempera-

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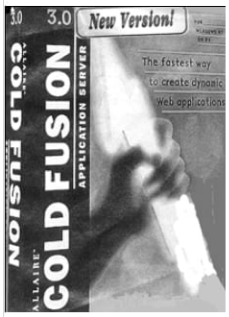
ture. Such a miraculous material would be a quantum leap better than long-sought room temperature superconductors, which would only carry electricity friction-free, without energy loss. A negative resistance material would actually create electricity."

Cole quoted mechanical engineer Cetin Cetinkaya of Clarkson University in Potsdam, N.Y.: "Negative resistance means you are generating power... Physically, that's not possible."

The *LA Times* report also quoted Jason Lo of the Canada Center for Minerals and Energy Technology. "If the effect is real," said Lo, then it could be "quite valuable...Whether it is an infinite source of energy, that is not known yet."

Cold Fusion: The Software

The new version of *Cold Fusion* is out, version 3.0, to be specific, and it costs only $999.95 in at least one catalog offer. The software publisher is Allaire. With the plumetting prices of software in general, this pricey gem must be mighty powerful, like the cold fusion *energy* source itself! We wonder why the developers chose to call their versatile software "cold fusion," which is not exactly a non-controversial name. This is what an ad for the software claims:



Powerful and dynamic Web applications at your fingertips!

Cold Fusion 3.0 Professional

Allaire offers a quick and easy-to-learn Internet site development program — Cold Fusion 3.0 Professional. It helps you create browser-based applications that support any browser technology including Java Forms, ActiveX Components, and Custom Tags. Plus, the easy-to-learn server-side Cold Fusion Markup Language enables you to improve your HTML knowledge so you can create dynamic Web applications quickly and easily!

Using the multi-threaded Cold Fusion Application Server, this program exploits key databases and Web technologies—making it easy for you to handle large scale Web applications. Cold Fusion supports ODBC-compliant data bases, including Sybase, Oracle, Informix, DB2, and Microsoft SQL Server. Plus, the Application Server offers text indexing and searching.

In addition, Cold Fusion 3.0 professional gives you control of your technology investment. Seamlessly integrate Cold Fusion Applications with your existing Web and Internet site for faster and more cost-effective development and deployment. It also supports Access, FoxPro, Paradox, and dBase—making them available for your workgroup!

Hot Fusion "Money Eater" to Collapse Soon?

ITER to get Congressional Ax in October?

The news is not good for the hot fusion boys and girls in the US. Not to worry for most of them, however, because the present $229 million/year US DoE budget for tokamak (magnetic) fusion will likely remain the same for the fiscal year beginning October 1, 1998.

It is another story for the big, fat $10 billion ITER (International Thermonuclear Experimental Reactor)—affectionally known by its opponents as the "money EATER." ITER, which has long been delayed, redesigned, and endlessly replanned, may soon be terminated thanks to U.S. Congressional action. The six-year-old latest agreement among the four ITER funding partners, the U.S., Japan, Russia, and the European Union technically expired on July 21, 1998, but the groups are still talking to one another about future plans. The entire project is some 13 years old, and has been aimed at producing a prototype test reactor—with ever diminishing performance expectations. *No* hot fusion reactor on the planet has ever produced more energy output than input, while cold fusion cells of course exceeded breakeven even before 1989.

The most immediate cause for alarm by the U.S. hot fusioneers is the threat of a *likely* U.S. Congressional appropriations bill in September that recommends that DoE withdraw from the project. The withdrawal of the US would likely lead to Russian abandonment of the project, or so the Japanese hot fusioneers are said to fear. Ironically it is the House "Energy and *Water* Appropriations" Subcommittee that is set to ax ITER. A flurry of hot fusioneer politicking is going on right now to reverse what some are saying is a likely termination of ITER. Anne Davies, who heads the DoE magnetic fusion program, has gone so far as to plead for allowing DoE to sign the ITER extension agreement even though no money would be available! Quoted in *Nature* (6 August 1998, p. 511): "We need to be able to sign regardless of the money..." Hmm? A little trampling on the U.S. Constitution, eh?

Two key Republicans are involved with the prospective ITER termination: Joseph McDade of Pennsylvania who chairs the House Energy and Water Appropriations Subcommittee and James Sensenbrenner of Wisconsin, chairman of the House Science Committee. They want answers about the future of ITER that have not been provided. The hot fusioneers, as usual, are scurrying around proposing scaled-down plans for ITER—or a substitute for ITER—to allow their plans (i.e., "perpetual" funding) to continue. One of these plans is for so called "ITER Lite"—a mere $5.5 billion, instead of $10 billion.

President Clinton, who by August was certainly up to his eyeballs with other more publicized problems in hot fusion, was not expected to step in and veto an appropriations bill that would kill ITER. Let us all hope for a very welcome October surprise—the final demise of ITER. But don't count on it, the "Tokamak Mafia" are much more powerful than ordinary citizens can imagine.

William Richardson Confirmed as U.S. Secretary of Energy Despite Monica Lewinsky Tie

The U.S. Senate has confirmed President Bill Clinton's appointee to Secretary of Energy, the former U.S. Ambassador to the United Nations William Richardson.

Richardson will likely follow the path of other U.S. Secretaries of Energy—Admiral Watkins in the Bush Administration, and Hazel O'Leary and Frederico Peña in the Clinton Administration and will totally ignore scientific developments in cold fusion and low energy transmutation.

It is worth noting that for a short time Richardson's appointment as Energy Secretary hung in the balance, as Senators considered his role in the Clinton-Monica Lewinsky affair. It is a matter of record the Richardson offered Monica Lewinsky a public affairs position at the

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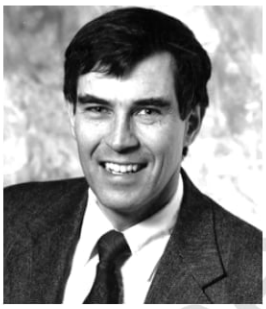
United Nations, via an as yet incompletely understood chain of command from the President. Controversy had erupted over whether the job offered to Lewinsky was already in place at the UN or was specially created. Would that Mr. Richardson, a former Congressman from New Mexico, had spent as much time investigating cold fusion as he did helping to place Lewinsky in New York.

Work on cold fusion has proceeded apace in Richardson's own home state of New Mexico, despite the DoE's official negative position on the discovery.

A message to the future Energy Secretary: If he needs people to work on helping him investigate cold fusion at DoE, there are plenty of cold fusion scientist volunteers waiting in the wings—and they will work for free! All he has to do is call us. (Guys, don't wait by the phone!)

Hot Fusion Man Dr. Rush Holt in Rush to Congress

Apparently not satisfied with his former position as Assistant Director at the Princeton Plasma Physics Laboratory. Dr. Rush Holt is running as the Democratic candidate for Congress in New Jersey's 12th Congressional District. It is not too difficult to imagine what his position will be on the continued funding of hot fusion, though his campaign literature so far does not emphasize this.



If Holt wins, he could become the fourth scientist to be in Congress at the present time. Congress now has: Vernon Ehlers (Republican, Michigan), a physicist; John Olver (Democrat, Massachusetts), a chemist; and Roscoe Bartlett (Republican, Maryland), a physiologist. In the November 1998 election of the U.S.'s 435 members of the House, Holt will face incumbent Republican Michael Pappas, who entered the House in 1996. Holt brands Pappas an "environmental extremist." One supposes this is because Pappas has not adopted Holt's "the sky is falling" position on "global warming."

Holt's campaign material pegs Holt as "teacher, scientist, Democrat." Whatever. One thing is certain, he has been a tireless campaigner in the past for hot fusion funding. While it may be true that Congress could use more scientists and engineers to displace lawyers in Congress, one thing *no* government body needs is another politician who will keep voting and politicking to fund the Federal hot fusion scam.

INE 98 SYMPOSIUM

A Successful Start - by Hal Fox

The INE 98 Symposium was held Friday and Saturday August 14-15, 1998 in the Saltaire Room at the University of Utah Union Building in Salt Lake City, Utah. This symposium is an extension of the New Energy Conferences sponsored by the International Association of New Science (IANS), which is now defunct or at least, sleeping. This Symposium was also a meeting of the INE membership.

SPEAKERS AND MESSAGES

The following are the speakers and summaries of their messages:

Tom Bearden: "EM Corrections Enabling a Practical Unified Field Theory with Emphasis on Time-Charging Interactions of Longitudinal EM Waves." This paper explored the time density waves and how they were related to the standard EM longitudinal waves. Bearden also covered some of the experimental evidence for such waves. Tom Bearden is one of the more prolific writers about new energy topics and his Cajun humor is always enjoyed.

Toby Grotz: "Preliminary Results of Electron Microscopy and Electron Diffraction Spectroscopy of Carbon-Carbon Arc Experiments." Toby reported on the latest successful attempts to provide transmutation evidence in the arcing of carbon rods on carbon materials. The evidence for the production of iron was shown. Considerable care must be taken to properly clean the carbon rods or carbon granules before experiments.

Gary L. Johnson: "Requirements for Bringing a New Energy Generator to Market." This presentation is essentially a verbal discussion of Chapter 8 of his book, *The Search for a New Energy Source.* This presentation presented a well-organized list of steps or challenges to be taken or met in getting a new energy product to market. Recommended was that work should proceed, as soon as practical, on both home-sized and substation sized systems as soon as a working method is available.

Don Reed: "Excitation and Extraction of Vacuum Energy via EM-Torelon Field Coupling - Theoretical Model." A historical survey of the torsion field was given. One aspect was explored mathematically to identify possible practical means by which the desired coupling between electro-magnetic fields and the torsion fields can be accomplished for power production. This topic is of considerable interest due to the increasing papers coming from Russia on torsion fields

Paul M. Brown: "Tritiated Amorphous Silicon Power Cells." This paper presented the application of tritiated amorphous silicon as an energy converter for betavoltaic devices. The recent resumption of the development of the nuclear battery was described. Batteries having a ten-year life (and no recharging) are possible using this technology.

Hal Fox and Shang Xian Jin: "Low-Energy Nuclear Reactions and High-Density Charge Clusters." The work sponsored by Trenergy, Inc. on the further development of the charge cluster technology originally discovered by Kenneth Shoulders was described. The paper discussed work with the LENT-1 reactor designed by the Cincinnati Group. One of the objectives of this work is to demonstrate that low energy nuclear reactions can be used for the stabilization of radioactive wastes.

Patrick G. Bailey: "The Need for Accurate Reporting and Archival of Data for Advanced Energy Conversion Devices: The INK Date Base." This presentation was both a description of the current INK database and a plea for members to add to or correct this database. Over 100 devices or systems for the production of new energy are stored on the database and ranked from initial report to replicated and ready for commercialization. Pat Bailey is the webmaster and the financial support for the prize winning New Energy Website at www.padrak.com/ine.

Moray B. King: "Overview of New-Energy Paradigms, Charge Clusters, and Torsion Fields." Moray gave an enthusiastic overview of various theoretical approaches to the tapping of zero-point energy. Various anomalies must be explained and appropriate experiments designed to buttress the further development of theory. Challenges to current experimenters to help provide data and or explanations for some of the observed results, especially with high-density charge clus-

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ters, was a part of the presentation.

David Yurth: "A New Approach to a Unified Field Theory." By viewing the torsion fields and the aether as the fundamental causes of electric fields, magnetic fields and gravity fields, Yurth outlined a new view for a Unified Field Theory which must include the torsion fields. Yurth suggests that all fields are effects arising from a universal, holographic causal plane described as the Physical Vacuum. Developments in Russia where torsion field research has been ongoing for more than 25 years was cited and some of the results in the development of new materials was explored.

Hal Fox: "The Superluminal Velocity of Gravity Waves." Fox reported on the life work of Gregory Hodowanec and Bill Ramsay in developing and using gravity-wave fluctuation sensors. It was described that these sensors show that celestial events can be measured (such as the transit of planets through the zenith of the earth's rotation) and that such events appear to be recordable at information transfer rates far exceeding the speed of light. The probable close relationship between gravity waves and torsion fields was presented.

Xian Liu Jiang: "Channeling Effects and Nuclear Reactions in Electrochemical Systems." Jiang reported on experiments to advance the understanding of the low energy nuclear reactions in cold fusion. Nuclear reactions have strong anisotropic behavior and are indicated by the measurement of charged particle beams that have been observed. Processes may be capable of development in which this transient process can be used to enhance the nuclear reactions by several orders of magnitude and bring about commercial applications.

Paul M. Brown: "Solving the Nuclear Waste Problem Through Applied Physics." The presentation was a tutorial on the effect of gamma rays on selected nuclear targets. Under appropriate energy levels a resonance condition assists in the interaction between gamma photons and nuclear reactions. By providing gamma photons at X-ray energy levels, the stabilization of selected radioactive wastes is being experimentally demonstrated.

Hal Fox: "New-Energy Anomalies." Laboratory findings, not consistent with current scientific models, were cited. The further exploration of these anomalies is one of the rewarding areas for scientific advancement. INE members were urged to share information on scientific anomalies.

Valarie Fredley: "A Brief Review of World Wide Concern and Support for Underdeveloped Cultures." Valarie is an executive employee of the Church of Jesus Christ of Latter Day Saints. She described some of the national and international activities of the newly-formed LDS Charities organization and its worldwide support for the help of people in need. Yalarie was Saturday's featured luncheon speaker.

NETWORKING

Attendees held two separate sessions in which members could network with each other and shares their goals, objectives, and queries. One of the most important summaries of the ensuing discussions is that Kenneth Shoulders is achieving good successes with the further development of high-density, charge-cluster devices for producing energy. Another important new member of INK is David Yurth, who is a key person in the funding for and planned development of torsion field generators and sensors. The consensus for new energy device commercialization is the following: The Hydrosonic Pump is already in production and being marketed. BlackLight Power (Dr. Randall Mills) hydrogen gas development is being funded by at least two electric utility companies. Some solid-state devices are being developed that appear to tap vacuum energy. For the future, one of the most promising technologies is the high density charge cluster technology.

PLANS FOR INE-99 SYMPOSIUM

Plans for INE-99 include the following: Summer 1999 in Salt Lake City, Utah with date to be established. Symposium to be coupled with new energy exhibits open to the public. New Energy companies will be invited to purchase booth space to demonstrate their products. Products are expected to range from publications to working new energy devices and support equipment. A Call for Papers will be published soon.

INE-98 SPECIAL ANNOUNCEMENT

Trenergy, Inc. (one of the corporate supporters of INE-98) announced its affiliation with the WHY Group and Nu Omicron Technologies, Inc. A two-year, two-million dollar development agreement has been signed. The project will emphasize the development of torsion field generators and sensors. An eight- to ten-person development team is being assembled. A suitable building is being purchased. Development work is expected to begin this fall. Trenergy, Inc. is a public company currently selling its shares in Utah and Nevada. David Yurth is CEO of the WHY Group. Hal Fox is President and S.X. Jin is the Chief Scientist for Trenergy. Trenergy plans to have a Website.

SPECIAL THANKS FOR INE-98 STAFF

The directors, officers, and members wish to thank the staff of INE-98 with special thanks to Robyn Harris (INE Treasurer and Office Manager of Fusion Information Center); Dineh Torres (Graphics Specialist); and Ede. Ede is a special INE volunteer. who has helped in all of the previous new energy conferences. In addition, Derrick Nakarishi gave freely of his time and talents to assist in making the conference a success.

TWO NEW MEMBER CLASSES ARE APPROVED

Three types of membership in the INE are now available: Member; Professional; and Corporate. Please contact INE for information regarding dues and individual membership privileges. (Hal Fox, Fusion Information Center, P.O. Box 58639, Salt Lake City, UT 84158; phone: 801-583-6232; fax: 801-583-2963).

Editorial continued from page 5

Did a "free energy" device emerge from the wreckage of the Third Reich and then disappear under the sands of time? Read Robert Nelson's historical review of the Hans Coler episode following World War II and draw your own conclusions. It is fascinating history.

Even more mind-wrenching is John Collins' book, *Perpetual Motion: An Ancient Mystery Solved?* We offer a variety of reviews. Can it be that in the early 18th Century, Johann Bessler was actually onto something that also disappeared for a much longer time than the purported Coler device? The delicious story entrains such luminaries as jealous antagonists Isaac Newton and Leibnitz. On the one hand, it is supremely difficult to believe that such a device could work at all, especially with what we know of gravity as a "conservative" force. On the other hand, the testing methods employed then and the verification efforts seem sound, at least at first glance. That may be one mystery that never gets answered. Or perhaps, like the recent proof of 300-year-old "Fermat's last theorem," a solution may leap out at us after centuries of time. Reading about Bessler and his travails can only help us to understand a bit more of the scientific revolution in which we find ourselves after all this time.

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Registration form, page 1
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Dr. Peter Glück (Institute for Isotopic and Molecular Technology)
New Sources of Energy: Scale-Up, Problems and Solutions

Dr. Thomas Phipps (Author, *Heretical Verities*)
Empirical Evidences of the Failure of the Lorentz Force Law

Jeff Kooistra (Physicist, Author, *Analog* Columnist)
Reaction Forces and the Marinov Motor—Physical and Social

Hal Fox (Trenergy, Inc.)
Commercial Development: New Energy and Transmutation

Dr. Paul Brown (CEO, Nuclear Solutions, LLC)
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The March for Peaceful Energy

There will be a press conference on the steps of the Capitol this October 24, 1998. The official large scale march (*IE*, Briefs, issue #20) has been postponed until October 24, 1999 due to additional time needed to organize such a huge event. For information regarding the event in 1999 or more information about the press conference, contact Richard Lasken, E-mail: PlantSeedK@aol.com or c/o DC Solar, c/o Univ. of Maryland College Park, Stamp Student Union, Box 73, College Park, MD 20742; website: http://www.indax.com/peace

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Institute for New Energy (INE) Symposium
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Dr. Peter Graneau (Northeastern Univ. for Electromagnetic Research)
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TAPE #2

Buford ("Ray") Conley
(MIT, graduate student, Dept. of Aero/Astro Eng.)
"Light Water Excess Heat Experiments"

Fred Jaeger (ENECO, Salt Lake City)
"Patents and Commercialization"

Professor Peter L. Hagelstein
(MIT Dept. of Electrical Engineering and Computer Science)
"Cold Fusion: What We Know and What We Don't Know"

TAPE #3

Professor Peter Hagelstein (Continued from TAPE #2)

Professor Keith Johnson
(MIT Dept. of Materials Science and Engineering)
"Progress in the Theory of Excess Heat" *and Excess Heat*- The Movie, now being made by Hollywood!

James L. Griggs
(Hydro Dynamics, Inc., Rome, Georgia, USA)
"The Hydrosonic Pump: Excess Power and Other Effects"

TAPE #4

Bertil Werjefelt (PolyTech(USA), Hawaii)
"Energy from Magnetic Materials and Magnetic Fields"

Dr. Eugene F. Mallove(Cold Fusion Technology, Concluding Remarks

The tapes include the speakers' presentations as well as question and answer sessions. There is footage of the Hydrosonic Pump under test as well as close-up footage of rotor surface melting effects. Bertil Werjefelt shows footage of experiments in his own laboratory. There are scenes of Japanese researchers from Sumitomo, Hitachi, and other companies and universities now involved in their claimed extraction of energy from magnetic materials. These efforts are now said by these researchers to be proceeding toward commercialization. Actual experiments are seen in progress. The tapes are VHS cassettes in NTSC format and range from 120 to 127 minutes each.

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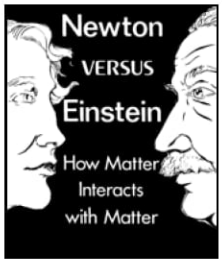

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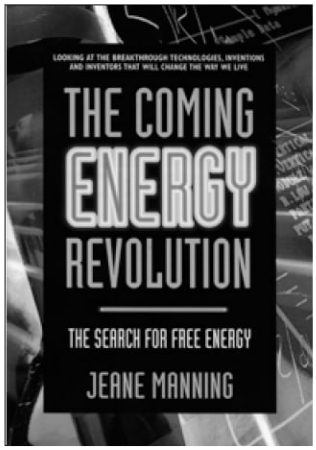

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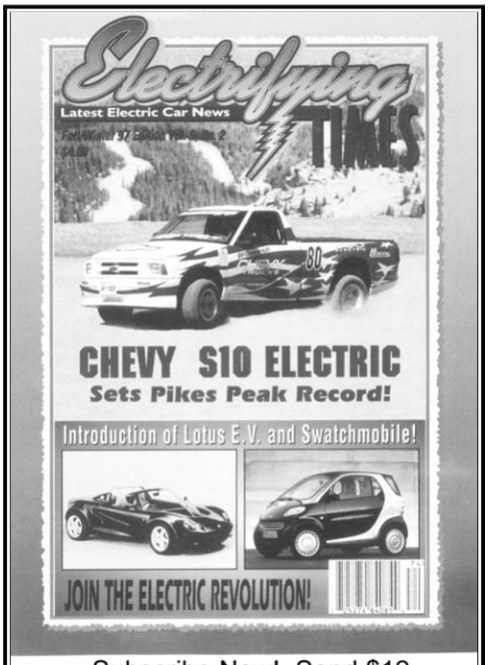

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A POSSIBLE SCENARIO FOR THE ONSET OF COLD FUSION IN DEUTERATED METALS

R. H. Parmenter

Department of Physics, University of Arizona, Tucson, Arizona 85721

At the suggestion of Sir Arthur C. Clarke, I am sending you the enclosed article. It was submitted for publication to *Physics Letters A* four years ago, but was rejected out of hand since "cold fusion doesn't exist." I would appreciate any comments you might have.
Sincerely, Robert H. Parmenter
Professor Emeritus of Physics, University of Arizona

A critique of this paper by cold fusion scientist and *Infinite Energy* Science Advisory board member, Dr. Robert Bass follows. His article as well as, abstracts from several other papers by R.H. Parmenter and Willis E. Lamb, Jr. and a more detailed letter from Prof. Parmenter.

Abstract

It is suggested that a pair of deuterons in a deuterated metal may resonant-tunnel through the Coulomb barrier separating them and forming a helium isomer characterized by $L = 1$, $S = 1$, and odd parity. The isomer can decay in several ways, each of which is analyzed, resulting in simple explanations of several surprising experimental observations: the very large tritium/neutron ratios, the association of excess heat with helium production, the difficulty in obtaining reproducible results. The validity of the scenario can be checked by looking for the nuclear magnetic moment of the helium isomer.

In a series of three papers, Parmenter and Lamb[1] demonstrated that conventional physics could explain the level of fusion processes observed by Jones *et al.*[2] in deuterated metals. A pair of deuterons can be trapped in a potential well in a tetrahedral cavity in palladium metal. The deuterons continually bang into the Coulomb barrier separating them with the characteristic frequency ω_0 of the harmonic-oscillator well. A large number of conduction electrons contribute to the screening of the Coulomb field of each deuteron. This screening is far more effective than is the corresponding screening by a pair of electrons in an isolated deuterium molecule. Thus the metal provides an environment conducive to enhanced Coulomb barrier penetration and resultant nuclear interaction.

The apparent lack of reproducibility of some experimental results has led some to insist that everything associated with cold fusion is spurious, with the possibility of some scientific fraud.[3] Nevertheless, there is growing evidence[4] that under certain conditions the amount of heat generated is well beyond what was observed by Jones *et al.*[2]. For a recent review of the field, see V.A. Chechin *et al.*[5]

Turner[6] originally suggested the possibility of a mobile deuteron *resonant tunneling* through the Coulomb barrier associated with a periodic array of deuterons in interstitial positions in the metal. This model has been further pursued by Bush[7] and by Bass[8], simplifying the model to a one-dimensional array. Kim[9] suggested the possibility of resonant tunneling associated with the Coulomb barrier separating two deuterons, but he apparently did not pursue the matter. The purpose of the present paper is to examine the consequences of the possibility of resonant tunneling of the Coulomb barrier separating two deuterons. I will show that this idea leads to simple explanations of several surprising experimental observations. Furthermore, the model leads to an unambiguous prediction that should not be too difficult to check or refute experimentally.

In order for resonant tunneling of the Coulomb barrier by a pair of deuterons to occur, it is necessary that there be some excited state of the pair having an energy equal or close to zero when the separation distance is in the nuclear interaction range R_0. I assume R_0 is the experimentally measured rms *diameter* of the α particle, *i.e.* $R_0 = 3.22 \times 10^{-13}$ cm. After all, the ground state of the deuteron pair is the α particle. The ground-state binding energy is

$$E_0 = (2m_D - m_\alpha)c^2 = 23.8458\text{MeV}. \tag{1}$$

I take the simplest possible model for the nuclear interaction potential as a function of the separation distance of the pair, namely a spherically symmetric rectangular potential well of radius $R = R_0\eta$, where η is some number close to one. Since each deuteron has a finite size, one might expect η to be slightly less than one. Since the height of the Coulomb barrier is approximately

$$E'_C = (e^2/R_0) = 0.447\text{MeV}, \tag{2}$$

we may consider the potential well to have an infinitely high wall when considering a zero-energy state. Thus the energies of the excited states are

$$E_{nl} = (\hbar^2/m_D R^2)(X_{nl}^2 - X_{10}^2) - E_0, \tag{3}$$

where

$$\left.\begin{array}{l} j_l(X_{nl}) = 0, \quad n = 1, 2, \ldots, \quad l = 0, 1, 2, \ldots, \\ (\hbar^2/m_D R^2) = 2.002176\eta^{-2} MeV. \end{array}\right\} \tag{4}$$

(Here j_l is the spherical Bessel function of order l.) Now the only reasonable possibility of a zero-energy excited state is the first excited state $E_{11} = 0$. Since $X_{10} = \pi$, $X_{11} = 4.4934095$, we get a vanishing E_{11} when

$$\eta = 0.93091, \; R = 2.9975 \times 10^{-13} \text{ cm}. \tag{5}$$

This is a zero-energy p-wave resonance of the two deuterons. The fact that it is p-wave ($L = 1$) is crucial to everything that follows.

If the spatial portion of the D_2 wavefunction is in a p-state, then this portion of the wavefunction is antisymmetric under interchange of the spatial coordinates of the two particles. Thus the spin portion of the wavefunction must be antisymmetric under interchange of spin coordinates (para-D_2), since deuterons are bosons. Each deuteron having a spin of 1, the pair might have spin 2, 1, or 0, but total spin 1 is the only choice that is antisymmetric.

Let $\mathbf{r}_1$ and $\mathbf{r}_3$ be the positions of the two protons of the deuteron pair, and let $\mathbf{r}_2$ and $\mathbf{r}_4$ be the positions of the two neutrons. The center-of-mass position of the deuteron pair is

$$\mathbf{R}_c = \tfrac{1}{4}(\mathbf{r}_1 + \mathbf{r}_2 + \mathbf{r}_3 + \mathbf{r}_4). \tag{6}$$

(Here I have made the approximation that neutrons and protons have the same mass.) Take

$$\mathbf{R}_{ij} \equiv \frac{1}{2}(\mathbf{r}_i + \mathbf{r}_j), \quad \mathbf{r}_{ij} \equiv (\mathbf{r}_i - \mathbf{r}_j). \tag{7}$$

Thus $\mathbf{R}_{12}$, $\mathbf{r}_{12}$ are the center-of-mass and internal positions, respectively, of one deuteron, while $\mathbf{R}_{34}$, $\mathbf{r}_{34}$ are the corresponding quantities for the other deuteron. The D_2 wavefunction can be written

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$$\Psi(\mathbf{R}_c, \mathbf{r}_{12}, \mathbf{r}_{34}, \mathbf{R}_{12} - \mathbf{R}_{34}, \sigma_{12}, \sigma_{34}) = \varphi(\mathbf{R}_c)\psi_0(\mathbf{r}_{12})\psi_0(\mathbf{r}_{34})\psi_1(\mathbf{R}_{12} - \mathbf{R}_{34})\Phi_1(\sigma_{12}, \sigma_{34}). \quad (8)$$

$\varphi(\mathbf{R}_C)$ is the center of mass wavefunction; $\varphi_0(\mathbf{r}_{12})$ and $\varphi_0(\mathbf{r}_{34})$ are the internal wavefunctions of the two deuterons; $\varphi_1(\mathbf{R}_{12}—\mathbf{R}_{34})$ is the p wavefunction describing the motion of one deuteron relative to the other; σ_{12} and σ_{34} are the spin coordinates of the two deuterons. I take the total spin state to have $S = 1$, $S_Z = 0$, so that

$$\Phi(\sigma_{12}, \sigma_{34}) = |1,0\rangle_{12,34} = \frac{1}{\sqrt{2}}\left[|1,-1\rangle_{12}|1,1\rangle_{34} - |1,1\rangle_{12}\,|1,-1\rangle_{34}\right] \quad (9)$$

When the two deuterons are within the nuclear interaction range, one should more properly consider a 4-fermion properly *antisymmetrized* wavefunction. Such a wavefunction is

$$\Psi_1 \equiv \tfrac{1}{\sqrt{2}}\Big[\Psi(\mathbf{R}_c, \mathbf{r}_{12}, \mathbf{r}_{34}, \mathbf{R}_{12} - \mathbf{R}_{34}, \sigma_{12}, \sigma_{34}) - \Psi(\mathbf{R}_c, \mathbf{r}_{14}, \mathbf{r}_{23}, \mathbf{R}_{14} - \mathbf{R}_{23}, \sigma_{14}, \sigma_{23})\Big]. \quad (10)$$

This wavefunction is properly antisymmetric under interchange of proton coordinates and under interchange of neutron coordinates. We have a zero-energy $^2He^4$ nuclear isomer (metastable excited state) of negative parity, total $L = 1$, and total $S = 1$, so that the total J may be 2, 1, or 0. We designate this isomer by the symbol $^2He^{4*}$. This excited state would not be noticed experimentally by low-energy deuteron-deuteron scattering or by photodisintegration of the α particle.

Let us consider four channels by which the isomer can decay. They are, respectively,

1) $^2He^{4*} \rightarrow {}^2He^4 + \gamma M1 + \gamma E1$,
2) $^2He^{4*} \rightarrow {}^2He^4 + \gamma M1$,
3) $^2He^{4*} \rightarrow {}^1H^3 + \gamma M1 + p$,
4) $^2He^{4*} \rightarrow {}^2He^3 + \gamma M1 + n$. (11)

Here $\gamma E1$ is an electric-dipole photon, $\gamma M1$ a magnetic-dipole photon; n is a neutron, $p = {}^1H^1$ is a proton, $t = {}^1H^3$ is a triton, and $\alpha = {}^2He^4$ is an α particle. The values of total energy release for each channel are

$Q_1 = 23.846$ MeV,
$Q_2 = 23.846$ MeV,
$Q_3 = 4.033$ MeV,
$Q_4 = 3.269$ MeV. (12)

Notice that in every channel a magnetic-dipole photon is emitted. This has the effect of converting an $S = 1$ state into an $S = 0$ state. Thus $|1,0\rangle_{12,34}$ is converted into

A portion of this state represents the situation where the two protons have antiparallel spins and the two neutrons have

$$|0,0\rangle_{12,34} = \frac{1}{\sqrt{6}}\left[|1,-1\rangle_{12}|1,1\rangle_{34} - 2|1,0\rangle_{12}|1,0\rangle_{34} + |1,1\rangle_{12}|1,-1\rangle_{34}\right] \quad (13)$$

antiparallel spins. To see this, write $|0,0\rangle_{12,34}$ in terms of the spin orbitals for the four fermions,

$$\begin{aligned}|0,0\rangle_{12,34} &= \frac{1}{\sqrt{6}}\Big[|\uparrow\rangle_1|\uparrow\rangle_2|\downarrow\rangle_3|\downarrow\rangle_4 + |\downarrow\rangle_1|\downarrow\rangle_2|\uparrow\rangle_3|\uparrow\rangle_4 \\ &\quad -(|\uparrow\rangle_1|\downarrow\rangle_2 + |\downarrow\rangle_1|\uparrow\rangle_2)(|\uparrow\rangle_3|\downarrow\rangle_4 + |\downarrow\rangle_3|\uparrow\rangle_4)\Big] \\ &= \frac{1}{\sqrt{6}}\Big[(|\uparrow\rangle_1|\downarrow\rangle_3 - |\downarrow\rangle_1|\uparrow\rangle_3)(|\uparrow\rangle_2|\downarrow\rangle_4 - |\downarrow\rangle_2|\uparrow\rangle_4) \\ &\quad -|\uparrow\rangle_1|\uparrow\rangle_3|\downarrow\rangle_2|\downarrow\rangle_4 - |\downarrow\rangle_1|\downarrow\rangle_3|\uparrow\rangle_2|\uparrow\rangle_4\Big] \\ &= \frac{1}{\sqrt{6}}\left[2|0,0\rangle_{13}|0,0\rangle_{24} - |1,1\rangle_{13}|1,-1\rangle_{24} - |1,-1\rangle_{13}|1,1\rangle_{24}\right].\end{aligned} \quad (14)$$

The first term of the final result represents the situation where the two protons have antiparallel spins and the two neutrons also have antiparallel spins; the second term corresponds to both protons having spin up, both neutrons spin down; the third term corresponds to both protons having spin down, both neutrons spin up. Similarly, we have

$$|0,0\rangle_{14,23} = \frac{1}{\sqrt{6}}\left[-2|0,0\rangle_{13}|0,0\rangle_{24} - |1,1\rangle_{13}|1,-1\rangle_{24} - |1,-1\rangle_{13}|1,1\rangle_{24}\right]. \quad (15)$$

In terms of the four decay channels, the only portions of both Equations (14) and (15) that are of interest are the portions corresponding to antiparallel spins of protons and of neutrons. Thus, with probability (2/3), a magnetic-dipole emission leads to a state

$$\Psi_2 = |0,0\rangle_{13}|0,0\rangle_{24}\varphi(\mathbf{R}_c) \times \tfrac{1}{\sqrt{2}}\left[\psi_0(\mathbf{r}_{12})\psi_0(\mathbf{r}_{34})\psi_1(\mathbf{R}_{12} - \mathbf{R}_{34}) + \psi_0(\mathbf{r}_{14})\psi_0(\mathbf{r}_{23})\psi_1(\mathbf{R}_{14} - \mathbf{R}_{23})\right]. \quad (16)$$

Consider the three states described by

$$\Psi_3 = |0,0\rangle_{13}|0,0\rangle_{24}\varphi(\mathbf{R}_c)\psi_0'(\mathbf{r}_{13})\psi_0'(\mathbf{r}_{24})\psi_1'(\mathbf{R}_{13} - \mathbf{R}_{24}), \quad (17)$$

$$\Psi_4 = |0,0\rangle_{13}|0,0\rangle_{24}\varphi(\mathbf{R}_c) \times \tfrac{1}{\sqrt{2}}\left[\psi_2(\mathbf{r}_{24}, \mathbf{r}_1 - \mathbf{R}_{24})\psi_3(\mathbf{R}_{124} - \mathbf{r}_3) + \psi_2(\mathbf{r}_{24}, \mathbf{r}_3 - \mathbf{R}_{24})\psi_3(\mathbf{R}_{234} - \mathbf{r}_1)\right], \quad (18)$$

$$\Psi_5 = |0,0\rangle_{13}|0,0\rangle_{24}\varphi(\mathbf{R}_c) \times \tfrac{1}{\sqrt{2}}\left[\psi_2'(\mathbf{r}_{13}, \mathbf{r}_2 - \mathbf{R}_{13})\psi_3'(\mathbf{R}_{123} - \mathbf{r}_4) + \psi_2'(\mathbf{r}_{13}, \mathbf{r}_4 - \mathbf{R}_{13})\psi_3'(\mathbf{R}_{123} - \mathbf{r}_2)\right]. \quad (19)$$

Here $\mathbf{R}_{ijk}$ is the center-of-mass coordinate of particles i, j, and k. In Equation (17), ψ'_0 describes the internal motion of the proton pair and of the neutron pair, while ψ'_1 describes the relative motion of the two pairs in a p wave. In Equation (18), ψ_2 describes the internal motion of a triton, while ψ_3 describes the relative motion of the triton and a proton in a p wave. In Eq. (19), ψ'_2 describes the internal motion of a $^2He^3$ nucleus, while ψ'_3 describes the relative motion of the $^2He^3$ and a neutron in a p wave. Note that Ψ_2, Ψ_3, Ψ_4, Ψ_5 all have identical values of L, S and parity, namely 1, 0, -1, respectively. In general, there will be some wavefunction overlap between $\Psi 2$ and each of $\Psi 3$, $\Psi 4$, $\Psi 5$.

In channels 1 and 2, the emission of an M1 photon converts Ψ_1 into the intermediate virtual state $\Psi 3$. Unlike Ψ_1, Ψ_3 probably has a large energy linewidth. Nevertheless, the mean energy of Ψ_3 is similar to that of Ψ_1. This suggests that, on the average, the M1 photon takes up a rather small portion of the available reaction energy $Q_1 = 23.846$ MeV. In channel 1 the final state is achieved by emitting an E1 photon, with energy close to Q_1, thereby removing the orbital angular momentum $L = 1$, allowing the final ground state to have $L = 0$. The energy of a 24 MeV gamma ray is on the high side for absorption by Compton scattering and beyond the threshold for absorption by pair creation[10]. The absorption mean free path of such a photon is 5.3 x 10^4 cm in air, 64 cm in water, 1.9 cm in palladium metal. The absence of experimental observation of such a photon suggests that channel 1 is an unlikely mode of decay. I will assume that it is the least likely of the four channels.

In channel 2 the final state is achieved by the α particle being in a free-particle p-wave state with kinetic energy close to Q_2. The recoil momentum is taken up by the palladium metal as a whole. In this sense, channel 2 is analogous to the Mössbauer effect, only there the recoil momentum counterbalances that of a photon rather than an α particle. What is the mechanism that allows the internal energy of the intermediate state to be converted to center-of-mass kinetic energy in the final state? The answer is that there is a coupling between the internal motion and the center-of-mass motion. Consider the harmonic-oscillator potential well in a tetrahedral cavity in palladium metal. A deuteron in such a cavity experiences a force having an associ-

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ated spring constant of $k = m_D \omega_0^2$. The antiparallel-spin proton-pair composite particle of the intermediate state thus has a spring constant $2m_D\ \omega_0^2$ (because of the charge +2e), while the antiparallel-spin neutron-pair composite particle has zero spring constant (because of zero charge). (As before, I am here making the approximation that neutrons and protons have the same mass.) The Hamiltonian for the harmonicoscillator forces now contains a term

$$H' = m_D \omega_0^2 \ \mathbf{R}_c \cdot (\mathbf{R}_{13} - \mathbf{R}_{24}). \quad (20)$$

This is the coupling between internal and center-of-mass motion that allows decay via channel 2. I believe that in experiments where very large amounts of heating are observed this channel is the major source of the heat. The energy-loss mean free path of a 24 MeV α particle in palladium metal is approximately 4.5×10^{-2} cm.

In channel 3, the emission of an M1 photon converts Ψ_1 into the final state Ψ_4 involving a triton and a proton. In channel 4, the emission of an M1 photon converts Ψ_1 into the final state Ψ_5 involving $^2He^3$ and a neutron. In each of these two channels, the outgoing massive particles must be in a relative p state in order to preserve orbital angular momentum L. Thus there is a centrifugal barrier in each channel of value

$$E_L = (8\hbar^2 / 3m_D R^2) = 6.161 \text{ MeV}. \quad (21)$$

(Here I have used the approximation that the reduced mass is $(3/8)m_D$ in both cases.) In channel 3 there is added to this the Coulomb barrier

$$E_C = (e^2 / R) = 0.480 \text{ MeV}. \quad (22)$$

In this channel, the *minimum* possible height of barrier through which $^1H^3$ and p must tunnel is

$$E_L + E_C - Q_3 = 2.608 \text{ MeV}. \quad (23)$$

In channel 4, the *minimum* possible height of barrier which $^2He^3$ and n must tunnel through is

$$E_l - Q_4 = 2.892 \text{ MeV}. \quad (24)$$

We have the remarkable result that the tunneling process is more difficult in channel 4 despite the absence of a Coulomb barrier. It is consistent with experimental observations[11] of tritium/neutron ratios as high as 10^8. In actuality, the barrier heights will have values somewhat larger than those of Equations (23) and (24) since some of the reaction energy Q must be shared with the emitted magnetic-dipole photon, but the energy of the photon will be quite small in order not to quench the tunneling process. I believe that because of this tunneling proceas channels 3 and 4 are less likely than channel 2. As in channel 2, there is a term coupling internal and center-of-mass motion in channel 4. However, the tunneling process is optimized by allowing no transfer of energy from internal to center-of-mass motion.

Several experiments[12] have indicated a correlation between the production of large amounts of heat and the production of $^2He^4$. This is consistent with channel 2 being the primary mode of decay. During such an experiment there should be a mixture of normal $^2He^4$ and the isomer $^2He^4$ present. The latter is readily distinguishable from the former by the presence of a nuclear magnetic moment. By using nuclear magnetic resonance to test for the presence of the isomer, one should be able to check for the correctness (or falsity) of the present scenario.

The probability per unit time the two deuterons in a tetrahedral cavity will fuse is governed by the general expression

$$\lambda = A \,|\, \Psi(R) \,|^2, \quad (25)$$

where $\Psi(R)$ is the value of the two-deuteron wavefunction at the boundary of the nuclear interaction region. In the case of *nonresonant* tunneling,

$$A = 1.478 \times 10^{-16} \text{ cm}^3/\text{sec}. \quad (26)$$

In their most recent paper,[1] Parmenter and Lamb calculated a value

$$|\Psi(R)|^2 = 6.208 \times 10^{-8} \text{ cm}^{-3}, \quad (27)$$

resulting in

$$\lambda = 9.176 \times 10^{-24} \text{ sec}^{-1}, \quad (28)$$

In the case of *resonant* tunneling described in the present paper, we must replace A by

$$A' \equiv \frac{4}{3} \pi R^3 T^{-1}, \quad (29)$$

where T is the decay lifetime of the isomer $^2He^{4*}$. I assume

$$T = 2.592 \times 10^5 \text{ sec (3 days)}, \quad (30)$$

based on the experimental experience that large amounts of excess heat are generated only after running the fusion cells for long periods of time. Note that

$$A' = 4.352 \times 10^{-43} \text{ cm}^3/\text{sec} \quad (31)$$

is *smaller* than A by a factor of 10^{-27}. When resonant tunneling is occurring, the wavefunction in the nuclear interaction region increases by a small amount each time the two deuterons bang into the Coulomb barrier separating them (with the characteristic angular frequency $\omega_0 = 4.456 \times 10^{14} \text{sec}^{-1}$). Thus $\Psi(R)$ should be replaced by

$$\Psi(R) = (\omega_0 T / 2\pi)\Psi(R) \quad (32)$$

in Equation (25). This replacement is justified as long as

$$\frac{4}{3} \pi R^3 \,|\, \Psi'(R) \,|^2 << 1, \quad (33)$$

a condition that is invariably satisfied. For p-wave resonant tunneling, the value of $\Psi(R)$ will be less than that of Equation (27), since the Gamow penetration factor is now appropriate to a combined Coulomb-centrifugal barrier. I estimate this reduces $\Psi(R)$ by a factor of 10^{-2} at most, since the centrifugal portion of the barrier is negligible over most of the tunneling range of the zero-energy deuteron pairs. Putting in the numbers, we get

$$\lambda' = A' \,|\, \Psi'(R) \,|^2 = 9.129 \times 10^{-13} \text{ sec}^{-1}. \quad (34)$$

λ' is greater than λ by a factor of 10^{11}, more than large enough to explain the amount of excess heat seen in any experiment. It should be admitted that in Equation (32) I assumed that the resonant tunneling of a pair of deuterons went on undisturbed for the full lifetime of the isomer (3 days). In actuality, thermal motion of the lattice may interrupt the process in much shorter times.

The equilibrium separation distance of a deutron pair inside a tetrahedral cavity in palladium metal is

$$Rm = 0.37709 \times 10^{-8} \text{ cm}. \quad (35)$$

Considering the pair as a rigid rotator, the excitation energy of the p-state of the rotator is

$$(2\hbar^2 / m_D R_m^2) = 2.9199 \times 10^{-2} \text{ eV}. \quad (36)$$

This corresponds to a temperature of 66° Celsius. Thus there is a reasonable possibility of the deuteron pair being in the p-state at room temperature.

In order for resonant tunneling to occur, the energy of the deuteron pair must closely match that of the $^2He^{4*}$ isomer. The very great difficulty in obtaining reproducible results experimentally may well be a consequence of the difficulty in matching these energies. It has been observed experimentally[13] that the use of a pulsed mode of operation increases the production of tritium and excess heat. The pulsing may allow for energy matching on a periodic basis.

In conclusion, we have seen that the assumption of resonant tunneling of the Coulomb barrier separating two deuterons can

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lead to simple explanations of several surprising experimental observations: the very large tritium/neutron rations, the association of excess heat with $^2He^4$ production, the difficulty in obtaining reproducible results. The validity of the model can be checked by looking for the nuclear magnetic moment of the nuclear isomer.

I am greatly indebted to Robert W. Bass for renewing my interest in the process of resonant tunneling.

Acknowledgments

I wish to thank Louis Brown for pointing out that decay channels 3 and 4 can each occur without emission of a magnetic dipole photon. In each channel it is necessary only that the two emerging fermions have their spins parallel rather than antiparallel. The argument remains unchanged that the tritium/neutron is very large. Also channel 2 can occur without emission of a magnetic dipole photon provided that a conduction electron flips its spin when the helium isomer decays to the ground state. The absence of magnetic dipole radiation will increase the probability of decay in all three channels.

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More Cold Fusion in Metals: Corrected Calculations and Other Considerations (Palladium/Deuterons)

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Contributed by Willis E. Lamb, Jr., December 27, 1989

ABSTRACT A simple model of a metal containing deuterons is considered. The example of palladium is treated in detail. In contrast to a previous calculation, it is shown that the effect of screening of Coulomb fields by conduction electrons is sufficient to allow a deuteron pair to fuse at a rate of 10-18 sec-1, five powers of 10 larger than some experimental results. It is shown that the Oppenheimer-Phillips process enhances the rate by a factor of 1.77. Difficulties with applying the model to titanium are discussed.

Proc. Natl. Acad. Sci. USA; Vol. 87. pp. 8652-8654, Nov. 1990, Physics

Cold Fusion in Palladium: A More Realistic Calculation (Deuterons/Thomas-Fermi-Mott)

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Contributed by Willis E. Lamb, Jr., July 16, 1990

ABSTRACT The Thomas-Fermi-Mott equation is modified to take account of the fact that conduction electrons in a metal may be considered to have an effective mass at wavenumbers comparable with or less than the inverse Debye screening length, but they should be considered to have the free-electron mass at much larger wavenumbers. This modification allows for a more realistic calculation of the fusion rate of deuteron pairs in palladium, this rate being 10-23 sec-1, comparable with some experimental results. The Oppenheimer-Phillips process enhances the rate by a factor of 2.262.

Proc. Natl. Acad. Sci. USA; Vol. 86, pp. 8614-8617, Nov. 1989, Physics

Cold Fusion in Metals (Deuterons/Palladium)

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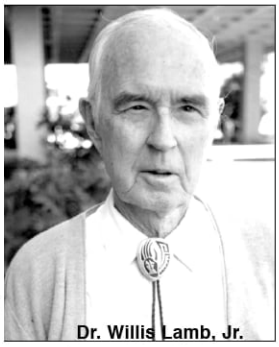
Contributed by Willis E. Lamb, Jr., July 31, 1989

ABSTRACT A simple model of a metal containing deuterons is considered. The example of palladium is treated in detail. It is shown that the effect of screening of Coulomb fields by conduction electrons is sufficient to allow deuteron pairs to fuse at rates of 10-30 sec-1, seven orders of magnitude smaller than those reported by Jones et al. [Jones, S. E., Palmer, E. P., Czirr, J. B., Decker, D. L., Jensen, G. L., Thorne, J. M., Taylor, S. F. & Rafelski, J. (1989) Nature (London) 388, 737-740].

Recent letter from Dr. Parmenter.

Dear Dr. Mallove:

Thank you for your letter of July 13 [1998] and your very kind words. It is nice to know that my article will be published after four years. I hope it will serve to stimulate experimentalists to look for helium atoms with a nuclear magnetic moment under conditions of excess heat production. It is particularly appropriate that Bob Bass write the commentary.


Dr. Willis Lamb, Jr.

Let me give you a bit of history. In 1988, Willis Lamb and I started working on cold fusion. After finishing our first paper, Willis called the editor of Physical Review Letters, a personal friend, and learned that there was no possibility of our publishing in that journal. Willis being a member of the National Academy of Sciences, we published in their proceedings. After our third article, the editor of the proceedings made it clear that he didn't want to see any more articles on cold fusion. I'm sure Julian Schwinger was treated in a similar fashion.

In May, 1994, while working on chaos theory, I received a call from Bob Bass asking about the three articles Willis and I had written. The resulting correspondence stimulated me to start thinking again about resonant tunneling in quantum mechanics. Two months later, I had completed the paper you are about to publish. During this time, Willis Lamb was in Europe. After returning and seeing the paper, he was initially very skeptical, in part because of unfamiliarity with the kind of spin algebra used on page four of the manuscript. He has since changed his mind, telling me he considers the paper important. He has also told me several times how pleased he is with the three papers we wrote together.

In August, 1994, I submitted the article to an editor of Physics Letters A, who had previously published several articles dealing with cold fusion. Without telling me, my article was shifted to another editor, who promptly rejected it. I suspect that the accompanying referee's report was written by an individual at CERN who specialized in debunking cold fusion.

I am enclosing a check for $29.95 to pay for my subscription to Infinite Energy. This seems appropriate since I just canceled my subscription to Physical Review Letters.

Sincerely, Robert Parmenter

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Parmenter's Fundamental Breakthrough Contributions

by Robert W. Bass, M.A. Oxon, Ph.D.
Prof. of Physics and Astronomy, BYU, 1971-81 [retired]

Noting Dr. Parmenter's acknowledgment to me at the end of his seminal paper, Dr. Mallove has asked me for a prefatory critique. Frankly I feel like a kindergarten finger-painting dauber asked to appraise a Rembrandt! In fact, in 1994 I applied seriously for a humble programmer's job at the Univ. of Arizona in hopes that by moving to Tucson, I might be able to audit some of Parmenter's courses: I am awed by his mastery of the three-dimensional details, not only of Quantum Mechanics (QM) [which I know only as a 1-D point-particle theory] but of Quantum Electrodynamics (QED), Nuclear Physics, and Solid-State Physics. I accepted this assignment only in hopes of nudging people like Dr. Barry Merriman of UCLA and Dr. Jim Peebles of Princeton to consider Parmenter's contributions with the serious care which they manifestly deserve. I'd also hope that in the next issue of *IE* we receive comments on this milestone theoretical *tour de force* by all of the dozen other expert theoreticians mentioned below.

Recently I sent a copy of the Parmenter paper, together with an implied apology for the short deadline, to the pre-eminent astrophysicist/cosmologist and current *Albert Einstein Professor of Science* at Princeton University, Dr. P.J.E. Peebles, whose opinion seems to me to be the key-stone of conservative skepticism about CF, as explained in (b) below. I have just received this e-mail from him:

> Hello, Robert Bass,

I did look over the paper by Parmenter. He got to the right physics in equation (25), but I believe messed up in the computation of |Psi (R)| equation (27), and I can make no sense of his resonance equation (32). In short, I see no reason to change my opinion. > Regards, Jim Peebles

This comment enhances Peebles' well-deserved reputation for astuteness, because there is no doubt that he has put his finger on the least-obvious and most questionable step in Parmenter's work, and I hope that Parmenter himself will elaborate in the next issue of *IE*; meanwhile, attempting to elucidate and justify this aspect of Parmenter's *magnum opus* provides me with an opportunity to bring to those interested in this matter what I regard as a truly excellent tutorial comment on some of the relevant background physics in a private e-mail debate which I had with my young friend Dr. Barry Merriman during March-July of 1997.

Dr. Merriman, an Assistant Prof. of Mathematics at UCLA, has for long been an accredited/recognized researcher at the DoE-funded [hot] Fusion Energy Research Program at UCSD. He is also open minded about the possibility that Low Energy Nuclear Transmutations (LENT), including Cold Fusion (CF), may be merely elusive rather than illusionary physical phenomena, and has given me several constructive suggestions [such as labeling a proffered talk to a physics department "lattice-catalyzed fusion" rather than CF in order to be less provocative]. He also acknowledges that a rigorous or highly plausible demonstration that LENT or CF is not truly forbidden would be an epochal scientific accomplishment, which [despite my status as an amateur who only knows some 1-D point-particle Quantum Mechanics (QM)] has spurred me to a considerable amount of work on the subject. In 1994 I gave Barry, in typescript, a one page [Nat.Acad.Sci.-level], a 100-page [archival-journal, university-level], a 35-page [semi-popular, tutorial, college-level], and a seven page [high-school-level] paper which, whatever their absolute merits, purport to: (a) be mathematically rigorous; (b) point out grievous flaws in the "best" published *CF impossibility 'proof'* known to me, namely that in the final half-dozen or so pages and exercises at the end of Chapter 1 of the admirable book on QM (Princeton Univ. Press) by the eminent Albert Einstein Prof. of Science at Princeton, Dr. P.J.E. Peebles; (c) patch-up genuine flaws in the pro-CF papers by the late Nobel Laureate in Physics, UCLA Prof. Julian Schwinger, which had been pointed out to me in a handwritten fax from another Nobel Laureate in Physics, Cambridge Univ. scientist Dr. Brian Josephson, around 1990 or 1991; (d) carry forward the line of thought initiated in 1989 in a Letter to *Physics Today* by LANL hot-fusion researcher Dr. Leaf Turner, which stimulated to deeper investigation CalPoly-Pomona Physics Prof., Dr. Bob Bush, from whom I heard about it at an ASME meeting in San Francisco in November 1989; (e) following the "be eclectic" urging of Fusion Information Center founder Dr. Hal Fox, incorporate or at least partly-overlap the better points in theories put forth through 1994, in alphabetic order, by retired BYU hot-fusion-researcher and Physics Prof., Bass [Ba]; by Bush [Bu]; the NRL uncle-nephew team of Drs. Talbott Chubb and Scott Chubb [C]; Purdue Nuclear Physicist Dr. Yeong Kim [K]; Univ. of Arizona Emeritus Prof. of Physics, Dr. Robert Parmenter [P] (a collaborator with erstwhile pro-CF colleague Dr. Willis Lamb, a Nobel Laureate in Physics); EPRI theoretical physicist Dr. Mario Rabinowitz [R]; Schwinger [S]; and Turner [T] (next to whom I had once sat for two weeks as a summer visitor to Los Alamos).

To dispose of the last item (e) first, recall that in 1994 I distributed widely a chart giving in the left-hand column 18 items, which it seemed to me, any respectable CF theory should consider [although if I redid it now I would want to include investigations of lattice phonons by *CF Times* editor Dr. Mitchell Swartz and MIT EE Prof., Dr. Peter Hagelstein, etc.] To save space I here list the items and, after each, the initials of those of the eight theorists of (e) who considered the item:

1. ZPF/LV (Zero Point Fluctuations and Lattice Vibrations): Ba, Bu, C, K, P, R, S, T.
2. Schwinger Ratio σ : Predicted Significance: S; Provided Λ for $\sigma = L/\Lambda$: C; First-Principles-Derivation Prediction: Ba.
3. Phonons: Fusion Heat Mediation and Inverse-Moessbauer-Effect Ion Excitation and De-Excitation: Ba, Bu, C, P, S.
4. QRT Ion Excitation: Resonant Non-Elastic-Collision Criterion, σ/π = ODD: Ba, Bu.
5. Globally Valid Potential $V(r)$: OK Near Collision: Ba, C, K, P, R.
6. Velocity Distribution: Fusion Rate Enhancement: K, R; Resonance Line-Broadening: Ba, Bu.
7. Periodic $V(r)$: In Solid-State Lattice: Ba, Bu, C, R, T.
8. Floquet-Bloch Theorem: $\{(\nabla\psi)/\psi\}$ Required Spatially Periodic: Ba, Bu, C, T.
9. Effective Δ-Mass: From Periodicity of $V(r)$: P, R.
10. Electron Screening: Fusion Rate Enhancement: Ba, C, K, P, R, S.
11. Madelung Forces: Fusion Rate Enhancement: Ba, C, P, S.
12. 3-D: 3-D Moessbauer-Analysis OK: C, P; Conduction Electrons in Host Lattice ($\Rightarrow \Lambda$): Ba, C, P.
13. Duane's Rule: For Inelastic Collisions and Resonant Transmission: Ba, Bu, C.

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14. Resonant Transparency Energy Levels: Ba, Bu, P, T.
15. Nuclear Well Present: Ba, P.
16. Heat vs. Loading Prediction: Bu.
17. Heat vs. Current Prediction: Bush TRM Fine Structure: Ba, Bu.
18. QRT: Host-Lattice Suitability for Deuterons vs. Protons Prediction: Ba.

The expert reader may wish at this point to read Appendix 1 and then inspect the MATLAB computer program in Figure 1 and look at the results of running the program eight times displayed in Table 1. Note that if one follows Parmenter and takes the width of a square-wave approximation to the Coulomb barrier to be the measured diameter of the influence of the strong nuclear force, the tunneling time is in femtoseconds; however, if one gradually takes the width to be ten times, 100 times and then 1000 times larger, an amazing consequence of physical nonlinearity is revealed. When the width is taken to be 100 times larger, the tunneling time is in microseconds, but when an additional factor of 10 is used, then the tunneling time suddenly changes to scores or thousands of billions of years! This is an example of mathematical Catastrophe Theory (a tiny parameter change wreaks radical change in the predictions of the model) and/or Chaos Theory (incredible sensitivity to changes in initial and boundary conditions—such as in the notorious Butterfly Effect in weather prediction or computed chaos in planetary dynamics).

Other readers may prefer to use the following debate between Bass and Merriman as a semi-popular tutorial which explains the derivation of the equations used in the MATLAB program.

What follows is an edited version of an e-exchange between Barry and myself from March 26, 1997 through the end of July, 1997. His words are prefaced by **M** and mine by **Ba**.

M: Resonant penetration simply takes a *long* time at low energies.

Ba: Did you not study my calculation of the penetration time when one includes in the calculation the ZPF and the uncertainty of the position of the bound deuterons?

M: Yes, I studied it in complete detail, and I fully understand your argument about ZPF line broadening. Further, that argument is probably correct, as far as it goes. The problem is your analysis is incomplete.

Ba: I came out that the tunneling time was only in picoseconds. Why do you continue to ignore this without refuting it?

MERRIMAN'S RESONANCE TUTORIAL

M: I neither ignore it nor refute it, because there is nothing wrong with that calculation. But we need to be clear on exactly what you have shown: what you show is that the uncertainty relationship dE dt > h implies that the time to complete the tunneling "must take at least" a few picoseconds, because dE is made bigger by ZPF broadening effects.

So, in effect, the uncertainty relationship is not a constraint on resonant penetration. I agree with you on that.

What you ignore is that the uncertainty relationship is *not the only time constraint* on the resonant tunneling process. The basic physics of resonant penetration imply a separate and much, much greater time constraint, totally independent of uncertainty issues.

Here is how resonant tunneling through a double barrier works, physically. I will consider in particular the case where the barriers are high and the waves are weak (since that is the case we are interested in). Each incoming wave is mostly reflected from the first barrier, but it transmits a small wave into the region between barriers. If the incoming waves are resonant with the space between the barriers, these small trapped internal waves add up constructively. In turn, these small internal waves are reflecting off the second barrier, transmitting a much, much smaller wave through that one. This second transmitted wave is observed as the net transmitted wave through the double barrier.

FIGURE 1

```
function [dt] = res_tunnel_01(R,E);
c = 3e008;                          % speed of light in m/sec
h = 4.136e-0015;                    % Planck's constant in eV-sec
Md_bycsq = 2*938.3*1e006;           % deuteron mass times c^2 in eV
Md = Md_bycsq/(c^2);                % deuteron mass in eV
el = R;                             % input potential barrier width in m
Ro = 3.22e-0015;                    % diameter of alpha particle in m
Uo = 447000*(Ro/el);                % height of potential barrier
Eo = E;                             % input energy of excited deuteron in eV
lambda = h/(2*pi*sqrt(2*Md*(Uo - Eo)));
                                    % de Broglie wavelength of excited deuteron
f = exp(-2*(el/lambda));
                                    % quantum-mechanical barrier penetration factor
N = 1/f^2;                          % number of bangs to penetrate
T = h/Eo;                           % period of bangs against barrier
dt = N*T;                           % time to penetrate Coulomb barrier in sec
```

TABLE 1

R [cm]	dt [sec]	
2.9975×10^{-13}	3.2027×10^{-15}	= 3.2 femtosec
3.2200×10^{-13}	3.5181×10^{-15}	= 3.5 femtosec
2.9975×10^{-12}	8.4208×10^{-13}	= 0.8 picosec
3.2200×10^{-12}	1.1332×10^{-12}	= 1.1 picosec
2.9975×10^{-11}	3.6331×10^{-5}	= 36 microsec
3.2200×10^{-11}	9.2480×10^{-5}	= 93 microsec
2.9975×10^{-10}	1.4202×10^{19}	= 45 billion years
3.2200×10^{-10}	2.3467×10^{20}	= 7,441 billion years

Once the internal trapped wave has resonantly built up to an *enormous* amplitude (much bigger than the amplitude of the incoming waves), it will be hitting the second barrier so hard that the wave transmitted through that barrier, while greatly reduced in amplitude compared to the internal waves, is as strong as the incoming waves. At this point, equilibrium is achieved and it looks like the incoming waves are perfectly transmitted through the double barrier.

So, the time it takes resonant penetration to occur is the time it takes the internal trapped wave to build up to a huge strength. Because it is built up from tiny contributions from each incoming wave, a huge number of incoming waves have to hit to reach this condition. *Thus, it takes a long time*. This is fundamental to the physics, and applies, for example, to systems such as water waves hitting a double obstruction like two parallel concrete "dams."

Based on this understanding, one can compute how long resonant penetration takes—assuming perfect resonance!—in any wave system, quantum or not, by figuring out how many incoming wave taps it takes to build up a huge internal wave strong enough to send a full amplitude transmitted wave through the second barrier.

Suppose a wave of amplitude A impinging on a single barrier makes a transmitted wave with amplitude fA, f << 1. In the double barrier case, these are internal waves and add constructively, so after N incoming waves have hit, the internal wave will have an amplitude A* = N fA. It in turn hits on the second barrier, which transmits a wave of amplitude f(A*) = f(NfA) = f^2 NA. In order for this to be the same amplitude as the incoming wave, we need A = f^2 N A, or N = 1/f^2 . This many waves must hit the double barrier for the (wave train)-(double barrier) system to reach the equilibrium where the net transmitted wave

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has the same amplitude as the incoming wave—*i.e.* the resonantly transparent state. Thus, the time it takes to achieve penetration is dt = N T, where T is the period of the waves.

In the quantum mechanical case, we have that the transmission factor f is the usual one-barrier tunneling factor, which goes like f ~ Exp(-w/w0), where w is the width of the barrier, and w0 is the wavelength of a particle with the same energy as the barrier height. Here, w is the width of the Coulomb barrier at the energy of the incoming particle (a few eV), which is roughly the Bohr radius, so, w ~ 10^-10 meters. Here w0 is the wavelength of a 10^6 eV particle, which is roughly about 300 x smaller, so f ~ Exp(-1000) ~ 10^-100, roughly. Thus, the number of wavelengths that must hit the barrier to achieve equilibration is N ~ 1/f^2 ~ 10^200. The period of these waves = the period of a ~ 1 eV particle, is T = 1/nu = h/h.nu = h/1eV ~ 10^-14 sec, so the time it takes to achieve resonant penetration is dt = N T ~ 10^200 * 10 ^-14 ~ 10^(several hundred) seconds. This is much longer than the current age of the universe, clearly.

What you must realize is that in the quantum case, there are two independent time constraints to consider: the first comes from achieving the resonant frequency, and that is controlled by the uncertainty principle. Your argument shows this time constraint is only picoseconds and thus of no consequence. But, even if the incoming waves have the *exact* resonant frequency, it also takes time to build up the internal trapped wave which is the mechanism by which transmission takes place. This latter process always takes a long time.

If you still cannot appreciate this, I will be glad to go over it in more detail but you are a good physicist, so I think it must be pretty clear to you based on the above. This is not a subtle point.

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BASS' REPLY

Ba: As I told you previously, you have done me a big favor by working up a heuristic "proof" that my Resonant Transparency of the Coulomb Barrier theory, while theoretically correct, would take too long for the tunneling to be physically meaningful.

In your view, the tunneling would take longer than the age of the universe; this is the "Jaendel objection," independently made by Rabinowitz and Worledge, which I believe I have refuted thoroughly in the "long" version of my Line Broadening argument (you referred to it only in the short, Heisenberg Inequality version, which provides a mere *inequality* instead of an equality).

However, I accept the validity of your heuristic argument. I just don't believe that your rough assumptions about the numbers to enter into your formulae are the ones that are appropriate.

When I go over your argument with care, instead of the "eons" which you get, I still get picoseconds (as in my typed papers).

I shall review your formulae in sequence [Figure 1] and get [Table 1] picoseconds instead of eons (using essentially your own notation and argument above). The sole change in notation is that I shall quote your tunneling factor f from Stauffer and Stanley, (*From Newton to Mandelbrot*, Springer, 1990, pages 93-94) as

$$f = \exp[-2(a/L)],$$

where a is the width of the barrier and L is the de Broglie wavelength of the particle whose waves are beating on the barrier. The decision to use as a = R the measured diameter of an alpha particle, with a concomitant barrier height U_O = 447 keV, is taken in imitation of the beginning part of Parmenter's paper.

Barry, I have used your own formulae, but entered the appropriate constants much more carefully than you did. Do you agree now that I have demonstrated that *standard* quantum mechanics "predicts" Cold Fusion when one considers a free deuteron excited to an energy level of 17 eV inside of a lattice of bound deuterons? Sincerely, Bob

MERRIMAN'S REJOINDER

M: We agree on the basic outline of the estimate. The only place we disagree is on the magnitude of "a," the effective width of the barrier. In my estimate, I said that "a" was on the order of a Bohr radius (~ 10^-10 meters), because that is the separation at which the Coulomb barrier starts to exceed the energy of the deuterium nucleus (~ 17 eV in your model), and thus that is the separation at which there is some sort of penetration barrier. Instead, you say above that "a" is about 100,000 times smaller, basically the separation scale at which the barrier assumes its peak height of ~ 20 MeV. The truth is obviously somewhere in between—the effective barrier is wider than the sort of "width at half maximum" you use above, and narrower than the "atomic separation width" I use.

My claim is that the truth is closer to my "a" than yours. You have computed the realistic Madelung potential, so in principle you can decide what its effective width is based on that. You say it is steeper than the basic Coulomb barrier—but I can't believe it's thousands of times steeper. If it is, I would agree with your estimate above, since the barrier would be thousands of times thinner than my estimate. But I bet even your detailed potentials have a barrier width of ~ 0.01 Angstrom if we measure the width where its height is 10,000 eV. If you do the tunneling time estimate above based on how long it would take the 17 eV particle to tunnel through a 10,000 eV barrier of thickness a = the width of your Madelung potential barrier at the 10,000 eV level, this would provide an underestimate of the penetration time (since the full barrier is at least as high and thick). I bet this would yield a very long time already, much much longer than the femtosecond times above.

More generally, if we let dt(a,U0) denote the estimated time to resonantly tunnel through a pair of barriers of height U0 and width a, as outlined above, what you showed is that dt(10^-15 m, 20 MeV) ~ femtoseconds, while I then showed that dt(10^-10 m, 20 MeV) ~ many many years. I think that if we let a(U) = width of the Coulomb barrier at height U, then dt(a(U),U-E) is always an underestimate of the time it takes the particle of energy E to penetrate (since the true barrier is at least as wide and high) and so the max over these estimates over all 0 < U < 20 MeV would give a decent simple estimate for the true tunneling time, and any one value sets a new lower bound. Of course, the real penetration factor f is some integral over the barrier which can be carried out---not sure if you have done so. The procedure just mentioned gives a simpler and cruder way to get a reasonable estimate.

In any case, we should argue about the appropriate value of "a" until we come to some agreement. Also, as you mentioned, you are free to divide the penetration time by the number of deuterons in the whole system, since even single fusion events would be interesting and detectable—thus you have a factor of ~ 10^16—10^23 to play with, but I suspect even that will not be enough to bring it down to a reasonable time.

RELEVANCE TO PARMENTER'S PAPER

Ba: I hope that the reader will find the preceding "unfinished debate" enlightening as a partial background to the Parmenter paper.

To my mind, the greatest achievement of Parmenter is that he

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has considered the problem of two nearby deuterons in their full three-dimensional and QM and QED and Nuclear-Physics detail. He shows convincingly that the nuclear reaction channels observed in fusion-temperature plasmas and in (gaseous) "Cold Fusion" of the Muon-Catalyzed type [studied by BYU Prof. of Physics, Dr. Steve Jones] are for the beyond-beta-phase ultra-loading scenario he (like Schwinger) has chosen to analyze, enormously less likely than the supposedly "impossible" d + d => He^4 observed by the most dedicated CF experimentalists. Also, Parmenter's theory is truly "scientific" in the sense of Popper, because, like all really valuable scientific theories, his theory makes highly specific predictions (observable by nuclear magnetic resonance testing of a working CF cell) which can be *"falsified if false."* Therefore if Parmenter's theory is fundamentally wrong, it would be quite possible to establish its failure by simply doing some measurements that have not been made to date!

It seems noteworthy that a genuine expert like Peebles finds no fault with the first 24 equations of Parmenter (which I regard as perhaps the paper's most enduring contribution), and endorses the linch-pin equation (25), but balks only at the numerical values in equation (27). There are two possible reasons which I can suggest as explanations. Peebles may have read the earlier papers by Parmenter and Lamb (P&L), and not agreed with some point; but I suspect it is more likely that, since those papers are in the *Proceedings of the National Academy of Science* to whose pages a Member like Lamb has automatic access without the hindrance of anonymous referees, Peebles may suspect that this work has not actually passed conventional "peer review" and therefore may be questioned as much as any self-published "Preprints" by unestablished wannabes like myself. However, this is not a fatal quibble, because the thrust of the earlier P&L papers was to arrive at a number consistent with published data; accordingly, it must be possible to justify the numbers in (27) by short *ad hoc* references to experimental data. Prof. Peebles' relentless skepticism is perfectly good science [Sir Arthur C. Clarke quotes Carl Sagan's dictum that extraordinary claims require extraordinary proof], and I must confess that I too was puzzled when I first came upon (32). It is evident to me (who would like to be convinced!) that Parmenter must have some background knowledge pertaining to resonance that is one of the *lacunae* in my own education, because he justifies (32) by (33) and I have not the faintest clue why (33) is relevant to the validity of (32)! Hopefully in the next issue of *IE* this matter will be elucidated by Dr. Parmenter.

Nevertheless, I have satisfied myself that (32) is physically plausible, by the following reasoning. Consider the well-known closed-form solution to a resonantly-forced harmonic oscillator

$$d^2\psi/dt^2 + \omega_o^2\psi = -\gamma \sin(\omega_o t),$$

and discard the [asymptotically irrelevant] bounded solutions in favor of the unique unbounded solution, whose maximum (after N bangs, when examined stroboscopically, at times $T_N = (2\pi/\omega_o)N$), is $(\gamma/[2\omega_o])(2\pi/\omega_o)N$, *i.e.* the maximum

$$\psi_N = (\gamma/[2\omega_o])\, T_N = N\psi_1, \qquad \psi_1 = \gamma(\pi/\omega_o^2),$$

grows linearly with time, and in fact *increases* by a *fixed amount*, $\psi 1$, after each bang. But this is *precisely* what (32) claims, when one notes that now

$$\{\omega_o T/[2\pi]\} = N.$$

Moreover, it is *reasonable* to take the two deuterons as behaving like a harmonic oscillator, because their far-potential is dominated by the term quadratic in r when the deuterons are trapped inside the tetrahedral cavity specified by Parmenter, and so the wavefunction ψ "increases by a small amount each time the two deuterons bang into the [near-potential] Coulomb barrier separating them (with the characteristic angular frequency $\omega_o = 4.456 \times 10^{14}$ per sec)."

Appendix 1
RESONANT TRANSPARENCY SPECTRUM OF COULOMB BARRIERS

In a poster paper at ICCF-5, I presented a more rigorous version of the following simplified quantum-mechanical derivation of the Spectrum of Energy Levels for a low-energy excited deuteron [energy between 6 eV and 150 eV] to find the Coulomb barriers of the two closest adjacent lattice-bound deuterons resonantly transparent.

It is known that a linear model of a 3-D lattice is adequate to predict the Moessbauer Effect, in which the recoil of a single nucleus affects an entire crystal. Hence, I have simplified the metallic lattice in which hydrogenic nuclides (protons or deuterons) are embedded from a 3-D model to a linear model. I have in mind a lattice of either palladium ions or nickel ions, but these do not appear explicitly; they serve as a ghostly background which establishes rigidly the distance between the positively-charged ions of interest. Therefore the only lattice analyzed is a proton or deuteron lattice.

First, consider a straight line $-\infty < r < +\infty$, with an excited particle located near r = 0. Next, place a bound positive unit charge at r = -L and another at r = +L. The excited particle then experiences a repulsive potential

$$V(r) = e^2\{ [1/|r + L|] + [1/|L - r|] \} = 2e^2\{ L/(L^2 - r^2) \},$$

which resembles an infinitely high "spike" as the particle moves left toward r = -L or right toward r = +L. Now imagine this potential repeated periodically so that there are spikes at r = j.L, for every positive or negative integer j = ±1, ±2, ±3, … The objective is to find conditions under which the excited particle finds all of these barriers "resonantly transparent," so that it can travel from left to right as if there were no barriers at all.

For present purposes, I shall simplify even this simplified model, and replace each of the spikes by a rectangular potential of finite height U_o and width $l << L$. Furthermore I shall consider only the central potential well and its immediate vicinity to left and right; therefore, we can shift the origin to the first barrier, and take the potential to be V = 0 in *region I*, r < 0, while it will be $V = U_o$ in *region II*, $0 < r < l$, and again V = 0 in *region III*, the potential well of interest, defined to be $l < r < L + l$. Similarly, the second barrier is defined as $V = U_o$ in *region IV*, $L + l < r < L + 2l$. Finally, we define *region V* as $L + 2l < r$, wherein once again V = 0.

I shall now derive quite rigorously from Schroedinger's wave mechanics and this crude model, a physical result which is identical to what I presented at ICCF-5 using a far more realistic potential. In that work, I place bound positive charges at every location r = j.L, for j = ±1, ±2, ±3, … and then model the effect of the circulating electrons (and *average* electrical neutrality) by placing bound negative charges half-way between every such pair of bound positive charges, except on the interval -L < r < +L. When one writes down the infinite series of these potentials, it turns out that they can be summed in closed form (analogous to the example above). It is physically required to consider all of these charges, because the ions are rigidly bound, and the electrons (by symmetry and neutrality considerations) *on average* may be treated as if bound (except in the central interval), and because electrostatic forces are long-range forces which in principle cannot really be screened out and must not be ignored [when their positions are fixed]. In this way I got a potential V = V(r) which is a Coulomb/Madelung potential. However, the line is not yet electrically neutral,

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because 3 electrons are missing, namely those on the central interval near r = -L, r = 0, and r = +L. From the papers of Parmenter and Lamb (and their references to the book of Mott), I learned how to include these final three charges as a "smeared out electron cloud" of negative charge distributed uniformly over the central interval, which results in a harmonic restoring force or quadratic potential $W = \omega_o^2(r^2/2)$ proportional to r^2, where the constant of proportionality, ω_o^2, is so chosen as to represent the effect of three electron charges. The final result is a Coulomb/Madelung/Fermi-Thomas/Mott potential $V(r) \equiv V_{C/M/FT/M}(r)$ which is defined only on the central interval $-L < r < +L$, but is then extended by definition to apply as a *periodic* potential $V(r) \equiv V(r + j.L)$, $j = \pm1, \pm2, \pm3, \ldots$ At this point I use what Drs. Scott Chubb and Talbott Chubb of the NRL refer to as the central result of solid-state physics, *Bloch's Theorem*, according to which no solution of Schroedinger's Equation is relevant in the present context unless its logarithmic derivative is spatially periodic of the same period as the potential. I am satisfied that the potential $V_{C/M/FT/M}$ derived as just explained, is extremely accurate because I have tested it as follows.

It is well-known in quantum physics that even at absolute zero temperature the bound ions in a metallic lattice continue to fluctuate in position, with what are called Zero Point Energy (ZPE) motions, or as a manifestation of Zero Point Fluctuations (ZPF). The rms amplitude Λ of such ZPF vibrations can be measured experimentally (*e.g.* by blurs on an x-ray, or from neutron diffraction studies). I call the dimensionless ratio

$$\sigma = (L/\Lambda)$$

the Schwinger Ratio, in honor of the late Nobel Laureate physicist (and Cold Fusion proponent) Dr. Julian Schwinger, because in his published and unpublished papers on CF he in effect conjectured that this ratio was all-important [and the possible significance of Λ for CF had also been pointed out in early CF studies by Dr. Mario Rabinowitz]. I have tested the validity of my periodic $V_{C/M/FT/M}$ potential by deriving from it a prediction of the value of the empirical Schwinger Ratio (which is about 22 for a beta-phase palladium lattice embedded with deuterons), and then confirming that the prediction is within one-third of one percent of measured reality!

Note that the Schwinger ratio includes the effect of the metallic *host lattice* (which establishes L) and also the effect of the mass M of the particle (whether it is a proton [M/2] or deuteron [M] affects Λ).

Therefore there is a definitively conclusive way to test the validity of my potential, which I call the *Rabinowitz acid test* because my good friend Mario had mistakenly opined that no known CF theory could pass this test. My *Quantum Resonance Triggering* (QRT) Criterion for CF with a given *host-lattice/particle* pair, whose foundation will be derived below, is that the pair is suitable for CF if and only *if σ/π is closer to an ODD than an even integer*. If one considers the host lattice to be either palladium or nickel, and the embedded particles to be either protons or deuterons, then there are four distinct possibilities. My QRT Criterion predicts that palladium will work well only with deuterons (thus justifying the use of protons as a "control" in Fleischmann-Pons types of electrolytic cells), while, conversely, protons will work better with nickel! This is because σ/π is a highly nonlinear function of the particle mass, whose value jumps from odd to even when in the case of a palladium host-lattice, the mass M of the particle [a deuteron] is divided by two to give the approximate mass of a proton!

The resonant transparency criterion to be derived below leads to one of my two derivations of the QRT Criterion, and is closely related to the computation of the energy levels of bound particles in a lattice. Using the numerical methodology given in a book of Dr. Steven Koonin for the latter, I have with $V_{C/M/FT/M}$ computed numerically the lowest 600 energy levels

$$E_n = f(n, \sigma), \quad (n = 0, 1, 2, 3, \ldots, 600),$$

[which ranges from about 6 eV to about 150 eV] of the Spectrum of Resonant Transparency for deuterons embedded in a palladium host lattice. I have also validated Schwinger's Conjecture by proving rigorously that this spectrum is a function of *nothing* but the fundamental constants of physics and the Schwinger Ratio σ.

The following Theorem will be proved here with the simplified potential defined above; however, it has also been proved (using the WBK approximate/asymptotic solution of Schroedinger's equation, which becomes numerically indistinguishable from the exact solution for all values of n other than the smallest few) in the case of the realistic periodic $V_{C/M/FT/M}$ potential described above.

THEOREM. Consider two rectangular [square-wave] potential barriers, each of arbitrarily great fixed height U_o and arbitrarily small width l, and spaced an arbitrary distance L apart. Suppose that a subatomic particle of mass M and kinetic energy $E < U_o$ impinges on the left-hand barrier while moving uniformly toward the right. Then [disregarding an asymptotically unimportant small bias which is relevant only for the smallest few 'multiples' mentioned below] a *necessary and sufficient condition* for the particle to tunnel quantum-mechanically through both barriers and emerge from the right-hand barrier still moving toward the right with the same energy is that the "well-width" distance L between the barriers should be an *odd integral multiple* of the particle's *quarter de Broglie wavelength* ($\lambda/4$), where $\lambda = h/\{2\pi(2M.E)^{1/2}\}$ and h is Planck's constant.

PROOF. As explained in introductory physics texts, the probability density of a particle is given by $|\psi|^2$, where the complex amplitude ψ is a solution of Helmholtz's Equation (the same equation which describes the configuration of standing sound-waves in pipe organs and which predicts the nature of standing electromagnetic waves in cavity resonators such as microwave ovens). After factoring out the time-behavior in the form of a sinusoidally-oscillating factor $\exp(2\pi i n t)$, where the frequency $\nu = E/h = 1/\tau$, the spatial behavior is governed by

$$\psi'' + k^2\psi = 0, \quad k^2 = (8\pi^2 M/h^2)[E - U],$$

so that $\psi = \exp(\pm ikr)$, depending upon whether the positive or negative square-root is chosen for the wave-number k. If we let j = 1, 3, 5 in *regions I, III, V* and let j = 2, 4 in *regions II, IV* as defined above, then there will be 10 constants (a_j, b_j) such that

$$\psi_j = a_j \exp(ikr) + b_j \exp(-ikr), \ (j = 1, 3, 5),$$

$$\psi j = a_j \exp(\kappa r) + b_j \exp(-\kappa r), \ (j = 2, 4),$$

$$k = (2\pi/h)(2M.E)^{1/2} = 1/\lambda, \ \kappa = (2\pi/h)(2M.[U - E])^{1/2},$$

and where, in the odd-numbered regions, the terms associated with the b_j coefficients provide (in the light of the time-factors) the waves which are traveling toward the right. Now define column 2-vectors $c^j = [a_j, b_j]' = [aj ; bj]$, where (as in MATLAB notation), apostrophes denote vector-matrix transposition of rows and columns, and where the semi-colon denotes stacking the next item in the next row (beneath the present row). As in pages 721-724 of Joos, *Theoretical Physics*, Dover (1986), the function ψ and its first derivative $d\psi/dr \equiv \psi'$ must be continuous at the 4 boundaries between the 5 regions, resulting in algebraic equations of the form

$M_j c^j = M_{j+1} c^{j+1}$, (j = 1, 2, 3, 4),

$M_1 = [1, 1; ik, -ik]$, $M_2 = [1, 1; \kappa, -\kappa]$,

$M_3 = [\exp(\kappa l), \exp(-\kappa l); \kappa.\exp(\kappa l), -\kappa.\exp(-\kappa l)]$,

$M_4 = [\exp(ikl), \exp(-ikl); ik.\exp(ikl), -ik.\exp(-ikl)]$,

Bass continues on page 59

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WHY FREE ENERGY IS MATHEMATICALLY AND PHYSICALLY POSSIBLE

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I. Introduction

In this paper, I would like to bring some simple mathematical proofs and discuss some physical concepts that show why free energy is indeed possible. The subject concerning the existence of free energy has already been discussed by several physicists such as T.E. Bearden[1,2] in two papers. However, it seems that most physicists do not realize that classical Newtonian mechanics does provide the answer concerning the existence of free energy.

The principle of conservation of energy is considered the most important principle in physics which has never been violated. Therefore, this principle seems to forbid the existence of free energy. This is not true. Most physics forgot to stress that the principle of conservation of energy is rigorously satisfied if a specific condition is fulfilled, namely that the force used in the physical process must verify Newton's third principle. We know that all the forces existing in nature do not necessarily verify this principle. These forces are generally called external forces. The existence of external forces which do not satisfy Newton's third principle deserves special attention since one must recognize, as shown below, that there is no energy conservation principle for that kind of force.

Most of our technology (motors and generators) does comply with the energy conservation principle because of Newton's third principle. It is the reason why the efficiency of motors and generators can never be higher than 100% because they work as closed systems. However, the existence of external forces does imply the existence of opened systems where the energy is provided by other particles located outside the system or by the medium. Therefore, classical mechanics does not forbid the existence of the so-called energy free devices or over-unity devices provided they use forces that do not satisfy Newton's third principle. The reader interested by this subject can consult the numerous web sites on free-energy devices. However, we can debunk the whole subject of over-unity devices by pointing out the existence of opened systems, a fact which is not well-known in the literature. In the case of an opened system, the efficiency can be higher than 100% because the work of the external force is not taken into account. The only question to be answered is how do we generate an external force? Since the Lorentz force can certainly not be considered as an internal force because this force does not follow Newton's third principle, therefore, the Lorentz force can be used for building the so-called free energy devices.

II. Newton's Third Principle in Newtonian Mechanics

It is fundamental to recall some basic definitions in classical mechanics (1-5). Newton's second law of motion states that the motion of two particles in a given reference frame is described by the differential equations:

$$\frac{d\mathbf{P}_1}{dt} = \mathbf{F}_{12} + \mathbf{F}_{11} \qquad \frac{d\mathbf{P}_2}{dt} = \mathbf{F}_{21} + \mathbf{F}_{22} \tag{1}$$

with the following definitions $\mathbf{P}_1 = m_1\mathbf{U}_1$ and $\mathbf{P}_2 = m_2\mathbf{U}_2$. We must distinguish between the internal forces $\mathbf{F}_{12}$ and $\mathbf{F}_{21}$ and the external forces $\mathbf{F}_{11}$ and $\mathbf{F}_{22}$ acting on the particles due to sources outside the system. We can speak of *mutual interaction* between two particles only if the internal forces follow Newton's third principle, namely $\mathbf{F}_{12} = -\mathbf{F}_{21}$. Therefore, an external force is by definition a force that does not follow Newton's third principle. When the external forces are zero, we say that the system is closed or isolated.

The center of mass of the system is a fictitious point $\mathbf{r}$ where the entire mass $m = m_1 + m_2$ of the system can be thought to be concentrated. It is defined by:

$$m\mathbf{r} = m_1\mathbf{r}_1 + m_2\mathbf{r}_2 \tag{2}$$

The motion of this point is only determined by the effect of external forces since we have:

$$\frac{d}{dt}m\mathbf{U} = \frac{d\mathbf{P}_1}{dt} + \frac{d\mathbf{P}_2}{dt} = \mathbf{F}_{11} + \mathbf{F}_{22} = \mathbf{F}_e \tag{3}$$

We can now study the motion of a second fictitious particle called the relative particle with a reduced mass $M = m_1m_2/(m_1 + m_2)$. This single particle is located at the place occupied by either the first or the second particle depending on our choice of the rest position as shown in Figure 1. The distance $\mathbf{R}$ is therefore $\mathbf{R}_{12} = \mathbf{r}_1 - \mathbf{r}_2$ if particle 2 is located at the origin of a reference frame or $\mathbf{R}_{21} = \mathbf{r}_2 - \mathbf{r}_1$ if particle 1 is now the origin of our reference frame. For each choice, we have an equation of motion:

$$\begin{aligned} \frac{d}{dt}M\mathbf{V}_{12} &= \mathbf{F}_{12} + \frac{1}{m}(m_2\mathbf{F}_{11} - m_1\mathbf{F}_{22}) \\ \frac{d}{dt}M\mathbf{V}_{21} &= \mathbf{F}_{21} - \frac{1}{m}(m_2\mathbf{F}_{11} - m_1\mathbf{F}_{22}) \end{aligned} \tag{4}$$

where the relative velocity $\mathbf{V} = d\mathbf{R}/dt$ between the two reference frames is reciprocal since we have $\mathbf{V}_{12} = -\mathbf{V}_{21}$. It follows that the reciprocity $\mathbf{V}_{12} = -\mathbf{V}_{21}$ of the rest reference frame is linked to the existence of Newton's third principle as shown in Figure 1 for the three possibilities. The reciprocity concept and Newton's third principle are two faces of the same coin. Therefore, we cannot use the reciprocity of the reference frames in special relativity and at the same time state that Newton's third principle does not apply in special relativity.

The splitting between internal and external forces is independent of the origin of the force, and therefore, this partition must apply in all branches of physics: classical physics, special relativity, electromagnetism and quantum mechanics. Therefore, special relativity and quantum mechanics are both incomplete theories, since they imply the existence of internal forces associated to the reciprocity concept and the conservation of energy and ignore the existence of external forces.

III. Conservation of Energy and Over-Unity Devices

By definition, the equation of conservation of energy must be satisfied:

$$\frac{d}{dt}\left(\frac{1}{2}m_1\mathbf{U}_1^2\right) + \frac{d}{dt}\left(\frac{1}{2}m_2\mathbf{U}_2^2\right) = \frac{d}{dt}\left(\frac{1}{2}m\mathbf{U}^2\right) + \frac{d}{dt}\left(\frac{1}{2}M\mathbf{V}_{12}^2\right) \tag{5}$$

When the external forces are zero $\mathbf{F}_{11} = \mathbf{F}_{22} = 0$, the system is closed or isolated, in that case, we get:

$$\frac{d}{dt}m\mathbf{U} = \frac{d\mathbf{P}_1}{dt} + \frac{d\mathbf{P}_2}{dt} = \mathbf{F}_{12} + \mathbf{F}_{21} = \mathbf{0} \tag{6}$$

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It follows that the velocity $\mathbf{U} = \mathbf{dr}/dt$ and the kinetic energy $E_K = m\,\mathbf{U}^2/2$ of the center of mass are constant or zero. Thus, Newton's third law can be interpreted as a law of momentum exchange. Hence a failure of the third law would be a failure of momentum conservation.

If the external forces are zero and the internal force F_{12} is derivable from a potential function $E_p(\mathbf{R})$, the equation of motion for the reduced mass becomes:

$$\frac{d}{dt} M\mathbf{V} = -\nabla_R E_P(\mathbf{R}) \tag{7}$$

One can multiply the two sides of the above equation by $\mathbf{V}$ to obtain:

$$\frac{d}{dt}\left(\frac{1}{2} M\mathbf{V}^2 + E_p\right) = 0 \tag{8}$$

Therefore, we have conservation of mechanical energy only in the case where the internal forces are central and satisfy Newton's third principle for translation. We can now give three well-known examples concerning the application of the principle of conservation of energy to a closed system.

The first example concerns the case of a simple non-relativistic harmonic oscillator of mass m_1 and spring constant k_0 fixed to a wall of mass $m_2 > m_1$. The equation of motion for the displacement of the mass is:

$$M\frac{d^2\mathbf{R}}{dt^2} = -\nabla E_P \tag{9}$$

where the internal force derives from a potential $E_p[\mathbf{R}(t)] = k_0\mathbf{R}^2/2$. Since k_0 is constant, the potential does not depend explicitly on time; therefore the system is closed and the mechanical or total energy E_T is also constant:

$$E_T = \frac{1}{2} M\mathbf{V}^2 + \frac{1}{2} k_0\mathbf{R}^2 = Ct \tag{10}$$

with the approximation $M \approx m_1$.

The second example is the case of a stone of mass m_1 dropped in the gravitational field of the Earth of mass $m_2 > m_1$. The potential energy between the two bodies is given by the relation:

$$E_P[\mathbf{R}(t)] = -G\frac{m_1 m_2}{R} \tag{11}$$

while the total mechanical energy conservation law has for expression:

$$E_T = \frac{1}{2} M\mathbf{V}^2 - G\frac{m_1 m_2}{R} = \text{Constant} \tag{12}$$

where $\mathbf{R}(t) = \mathbf{r}_s - \mathbf{r}_e$ is the distance between the stone and Earth considered as point particles.

The third example can be obtained by taking into account the relative motion between two charged point particles which is induced by a mutual potential electrostatic energy:

$$E_P[\mathbf{R}(t)] = \frac{q_1 q_2}{R} \tag{13}$$

with the energy conservation law

$$E_T = \frac{1}{2} M\mathbf{V}^2 + \frac{q_1 q_2}{R} = \text{Constant} \tag{14}$$

One must point out that the above energy conservation laws do not depend on the choice of a reference frame or an observer. Therefore, the existence of a medium such as the ether cannot be proved or disproved by these equations. However, the case is different if there exist open systems and the ether which can provide the energy needed to sustain the so-called free energy devices.

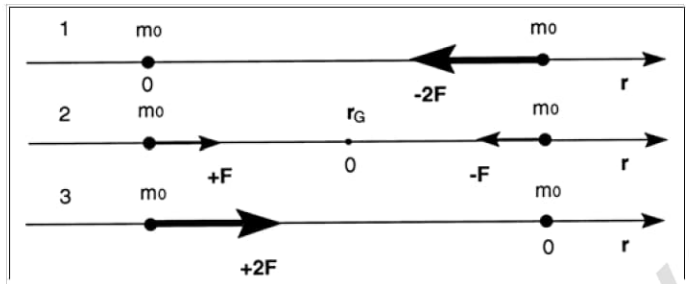

Figure 1. Three possible reference frames to describe the mutual interaction between two identical particles.

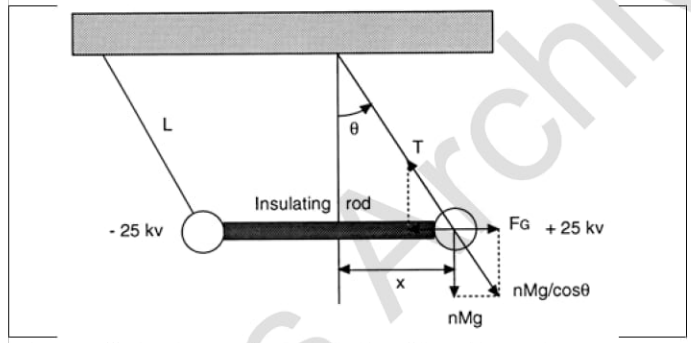

Figure 2. Various forces acting on a double solid pendulum (n=2).

IV. Charged Capacitor Pendulum Experiment

The violation of Newton's third principle by the Lorentz forces implies that a charged capacitor must accelerate its center of mass without external help if the capacitor has an absolute motion with respect to the ether. Moreover, the existence of an external force must also result in the violation of energy conservation. The experiment showing the linear spontaneous motion of the capacitor through the ether has already been reported elsewhere.[5-9] The experiment as shown in Figure 2 consists of two massive aluminum balls weighing 500 g each suspended by fine cotton wires to the ceiling of the laboratory. In order to keep the balls at a fixed distance D, an insulating rod is used between the balls. The bi-filar pendulum was placed in the middle of the laboratory room empty of any metallic object. The distances between the laboratory walls and the balls or the wires are about 2.25 m. The direction of the stimulated force and the resultant motion thereby produced by the external force are toward the positive electrode of the capacitor as shown by the experiment.

One of the methods used to measure the displacement of the pendulum consists to place a measuring wood rod parallel to the pendulum and takes a video movie of the experiment when the voltage is switched on and off. By measuring the amplitude of the oscillation one can determine the displacement which amounts to a few mm. The results are reliable since we can increase the effect to 5 cm by oscillating the high voltage. In that case, no measurement is indeed necessary to prove the existence of this effect.

In classical circuit theory, the generator, the wires and the capacitor form a closed system where the conservation law of energy for internal forces applies. Therefore, the energy E_S of the generator is converted into energy stored E_P in the charged capacitor and into heat E_R dissipated during the charging process, it follows the conservation law:

$$E_S = E_P + E_R$$

with: $$E_P = \frac{1}{2} CV_0^2 = E_R = \int_0^\infty RI^2(t)\,dt \tag{15}$$

If the capacitor is not perfect, there is a leaking current and a corresponding dissipated energy which is provided by the generator.

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Figure 2 shows a pendulum of mass 2M where M is the mass of one ball and L is the length of the string which makes an angle θ with the vertical. The forces acting on the system are the gravitational force 2M**g**, the tension **T** in the string and the stimulated force $\mathbf{F}_G$. The horizontal component of the tension force is balanced by the stimulated force F_G when the stationary state is reached, therefore we have $F_G = 2Mg\ tg\theta \approx 2Mgx/L$, where $x \approx L\ tg\theta$ is the displacement of the ball.

The above energy conservation law will be violated when there is a stimulated force $\mathbf{F}_G$ since we have now:

$$\frac{d}{dt}\left(\frac{1}{2}\ nMU^2\right) = \mathbf{U}.\ \mathbf{F}_T \qquad (16)$$

where $\mathbf{F}_T$ is the sum of the gravitational force 2Mg, the tension T in the string and the stimulated force $\mathbf{F}_G$. knowing that **U** is the velocity of the pendulum in the Earth's reference frame. When the generator is switched off, a kinetic energy $E_K = 2MU^2/2 = 2MLg(1\cos\theta) \approx Mgx^2/L$ is recovered. This energy cannot be given by the generator but is taken from the ether. For two balls charged at 50 kV, the kinetic energy of the pendulum is $E_K = Mgx^2/L \approx 1.4 \times 10^3$ ergs while the electrostatic potential energy is $E_p = CV^2/2 \approx 1.4 \times 10^5$ ergs. The kinetic energy due to the stimulated force is not a small quantity and cannot be taken from the generator since in classical circuit theory no motion of the capacitor is taken into account during the charging process. The effect is even more important if we applied the high voltage in an oscillatory manner in synchronism with the oscillatory motion of the pendulum. It results in an amplification of the magnitude of the displacement of the pendulum which now reaches ± 5 cm. This implies an increase of the kinetic energy almost 25 times the above kinetic energy.

One may think that the stimulated force is produced by the electrostatic forces resulting from the induced charges in the surroundings. Four tests were done to reject the hypothesis that the force is induced by the surroundings.

First test, we switch the polarity of the power supplies and observe that the direction of the force has also changed 180°. We recall that the direction of the force must not change if the spontaneous force is produced by asymmetries of the electrostatic forces.

Second test, we put a wood plate about 5mm near by the negative ball. When the voltage is increased, one can see the pendulum attracted by the induced charges in the wood plate, at about 30 kV when we increase the voltage above this value, then the spontaneous force takes over and one can see the pendulum moving away from the wood plate in the opposite direction.

Third test, we used coated wires to supply the balls, therefore the ionization current almost drops to zero, about 3 micro-amp. In that case, no more translation effect was observed even by oscillating the D. C. voltage.

Fourth test, when the ionization current is present, we oscillate the D. C. voltage and obtain an huge increase of the kinetic energy of the pendulum which proves that we are using an external force to produce work. We recall that an internal force can be distinguished from an external force by oscillating the potential function since for an internal force, the oscillating kinetic energy does not increase with respect to time as shown in equations 13 and 14 while for an external force the kinetic energy does increase as it is the case of a swing pushed by an external observer.

The earth magnetic force play no role in this experiment since the force involved is too small and not in the good direction.

One may also think that the stimulated force is produced by electrical wind or corona discharge. We must point out that the stimulated force does not exist if there is no current circulating inside the conductors. Let us recall that a current flows inside a conductor if there is a permanent non-uniform electrical field inside the conductor or inside the battery. There are several ways to produce this non-uniform field. For example, it can be produced by the presence of thin wires near by the balls as explained in the paragraph 6-11 high-voltage breakdown in the Feynman lecture book, see also the very important and not well-known paper by H. A. Pohl[10] dealing with this subject.

The current can also be produced by ionization of the air or by the leakage current in a dielectric. In the report by R.L. Talley[11] where the pendulum was in vacuum, no effect was observed because there is no current involved in the experiment except in one experiment where a dielectric was placed between the two electrodes. In that case, the observed effect can be explained by the leakage current in the dielectric. I think that this positive result justifies our viewpoint that a current is needed in order to produce a stimulated force through the violation of Newton's third principle. One can also criticize the experiment by noting that the voltage 19 kV is too small to show the effect. T.T. Brown used voltage up to 150 kV and obtained huge forces as indicated in P.A. LaViolette's book[12].

There are several possible mechanisms to explain the motion of the pendulum by an electrical wind effect:

The first one, the thrust results from the ejection of charged particles by the wires. Due to the cylindrical symmetry of the wires, the reaction forces must cancel to zero on the average.

The second one, electrons are attracted by the positive ball and the positive ions by the negative ball, due to the difference of mass of the two species of particles, the motion should be in the direction of the negative ball and cannot explain the thrust in the positive direction.

The third one, both negative and positive ions are attracted by the balls of opposite polarity. The transfer of momentum in the positive direction can be explained by a collision process and is due to the difference of mass between the two kind of ions. Let us assume that the spontaneous motion is due to a direct collision of both positive and negative ions with the metallic conductors. Then the transfer of momentum must be attributed to the difference of masses between the two kinds of ion, namely the masses of the emitted electrons. In A.D. Moore's book[13] (p. 84), it is stated that 6×10^{12} electrons per second leave the negative electrode for a corona amounting to 10^{-6} A. For a 1.5 mA leakage current in the pendulum experiment, we obtain 9×10^{15} electrons/s which amounts to a mass transfer 8×10^{-12} g/s which is several orders smaller than the 3.5 g stimulated force observed.

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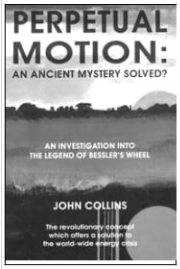
Perpetual Motion: An Ancient Mystery Solved? Comments by Eugene Mallove

John Collins' work of historical reconstruction, translation, and analysis, *Perpetual Motion: An Ancient Mystery Solved?*, is a monumental work by a man who has dedicated much of his life to what most people—and certainly most scientists—would agree is a hopeless cause: the study of an alleged machine that relies on only internal mechanical devices to produce external work, apparently indefinitely.



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Yet in Collins' well-written book, which is difficult to put down once begun, we have the incredible story of an early 18th century figure, Johann Bessler, who from all accounts appeared to have pulled off just such a feat. Do I believe that Bessler really did that? An emphatic "No!" and a "Yes!" There are compelling and fundamental reasons in physics to believe that it is impossible to make such a machine, but the historical evidence—particularly the methods that were employed to test the series of small and large wheels that Bessler created—are convincing (if, as I assume to be the case, there has been no tampering with the historical account through translation or omission).

Below Mike Carrell gives an excellent synopsis of what *Perpetual Motion* actually contains, but this is a work for which every detail will be critical to a reader's overall conclusion. Reader Steve O'Donnell, for example, at first was impressed that Bessler might really have accomplished this unthinkable scientific heresy. Later, he envisioned exactly how the trick might have been done—and we include his attempts to test his "remote magnet" hypothesis. Frankly, I do not see how the hidden magnetic manipulation of the wheels could have happened during the test conditions reported, but perhaps I am not imaginative enough. Then we have the sharp reaction of the always eloquent physics heretic, Dr. Thomas Phipps, Jr. He doesn't believe Bessler either, though Tom *dis*believes many things that most physicists *do* believe, such as the sanctity of Einstein's Special Theory.

One should read this book, because it portrays a human drama with significant parallels with the dynamics of other on-going controversies over purported "magical" devices and how they are tested. This book does not make the mistake of reducing complex historical happenings to a possibly false, simplified story of deception, as well-known encyclopedias have done for Bessler and others.

THE LEGENDARY WHEEL OF ORFFYREUS
A Review of *Perpetual Motion* by Mike Carrell

Infinite Energy magazine documents contemporary advances in the study of anomalous energy devices and systems. The present scene is the latest episode in a long drama whose earlier acts included alchemy and the search for perpetual motion, efforts widely discredited and seen at best as primitive precursors to modern science. Yet in the past year evidence for transmutations in electrochemical systems is found in many reports.

As for mechanical "perpetual motion," a recent book by John Collins presents strong anecdotal evidence that one man did learn to build self-moving wheels capable of doing substantial external work, and operating for weeks in a sealed room. Collins' book *Perpetual Motion: An Ancient Mystery Solved?*, subtitled *An Investigation Into the Legend of Bessler's Wheel*, is the culmination of 30 years' work.

The story of Johann Bessler, a.k.a Orffyreus, is well told and shows painstaking research. The story evokes a sense of deja vu, for the attacks upon Bessler, the demonstrations to notable people, the interaction of Bessler's personality with patrons and potential purchases, and the apparent loss of the technology are all reminiscent of the contemporary debates about cold fusion and related phenomena.

I will sketch the story as told by John Collins and invite readers of *Infinite Energy* to peruse the book for the wealth of detail which does credit to Collins' research and lends credibility to the legendary wheel.

Johann Bessler was born about 1680 and died in 1745 in the region now known as Germany. There is evidence that he was a prodigy, with some formal schooling, who cultivated learned men and skilled artisans and acquired an enormous range of knowledge and practical skills that enabled him to build his wheels while earning a living as a physician. During his travels, he saw a clockwork-powered spit in a monastery and resolved to search for a means of "perpetual motion," which was already a topic of speculation and experiment.

Johann Ernst Elias Bessler, also known as Orffyreus.

Orffyreus married and settled in the town of Gera, where he built his first wheel, about a meter in diameter. It "was mounted in such a fashion that anyone could walk all the way around it. On unfastening a bolt, the wheel immediately began to revolve. Whoever wished to push it or touch it at any point was free to do so. People could see there was no trickery involved." The sides of the wheel were covered to conceal the inner workings.

The wheel was open to the public, and all kinds of people came to see it. Close inspections were performed, and a certificate of its genuineness was granted. Some declared it a toy, incapable of useful work. If a larger one could be built, the claims would be believed. He was besieged with visitors and, in irritation, destroyed the wheel.

This pattern was repeated in following years. He moved several times, building larger wheels which were exhibited to the public and examined closely by scholars and officials. He was, of course, attacked. The whole story is laid out in Collins' book, but for this review I will extract some salient features of the wheel and its story.

Four wheels were constructed, each destroyed.

- at Gera, diameter approx. 1 meter;
- at Draschwitz, diameter approx. 3 meters;
- at Merseburg, diameter approx. 12 feet in diameter, bidirectional motion
- at Kessel, same as Meresberg.

The first two rotated continuously unless restrained, always in the same direction.

The Draschwitz Wheel could "raise a weight, placed twelve inches away from its axle, once every second."

The Merseburg Wheel was stationary at rest, but would accelerate to an operating speed of 26 rpm *in either direction* from an initial nudge. This design refuted critic's claims of an internal pre-wound clockwork mechanism.

At Gera, a formal examination of the first wheel was

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arranged and a certificate of authenticity granted by the local nobility. Collins notes: "The certificate, reproduced above [in Collins' book] is fine as far as it goes. Unfortunately it does not describe the tests done, nor for how long the machine ran. It relies largely on the belief that these were men of unimpeachable reputation and were therefore beyond criticism...reading between the lines, Johann Adam Cass, a surveyor and mechanician, was chosen to carry out the tests and supervise the actual examination. He would have been able to detect any signs of deception, although it could have been possible for such a small model to have been driven by clockwork...to suspect Orffyreus would subject himself and his machine to such an august gathering while secretly planning to deceive all of them, including his new found aristocratic friends seems doubtful."

A second test was arranged at Merseberg on October 31, 1715, on the authority of the Duke of Zeitz, Moritz-Wilhelm, who chose men to participate. The district magistrate was ordered to attend to make an official record. There were other, unofficial records of the test. The test was advertised in the *Leipziger Zeiungens-Blat.* A certificate describing the test includes:

"The inventor first put in motion his six ells (11.15 feet) in diameter and one foot thick machine, which was still resting on the same wooden support upon which it had previously been mounted. It was stopped and re-started, turned both left and right as many times as was requested by the members of the Commission, or the spectators. The machine was started by a very light push with just two fingers and accelerated as soon as just one of the weights, hidden inside, began to fall. Within about one revolution, the machine had acquired a strong and even rotation, even when a box was lifted, which had been filled with six whole bricks weighing together about seventy pounds. The weight was lifted by means of a rope conducted through a window by means of a pulley, eight ells (14.8 feet) upwards to the roof, and several Clafter (a Clafter is equal to about 8.2 feet) down into the yard. The box was lifted as many times as was requested.

"Furthermore the Inventor, Orffyreus, in front of everybody, lifted the perpetual motion machine described above, from its original wooden support. The timber posts were carefully examined both from the top and bottom as well as in the middle, particularly where a small cut was noticed. The same careful examination was devoted to the iron journals of the shaft and to the bearings. However there was not the least vestige of suspicion of fraud observed.

"By way of additional proof about its internal motive power, the perpetual motion machine was translocated to another support in such a way that the whole assembly could see over and under, and both sides of the machine; and all present were invited to visit the bearings, but no holes were found, all present examined them with their eyes, but no sign of fraud was there seen. [Note: before translocating the wheel, the internal weights were removed. Orffyreus' brother and assistant, Gottfried Bessler, helped him move the wheel—private communication from John Collins]. It was possible to translocate the machine and to turn it left and right as many times as was asked by the assembled respectable Commission. The machine regained its strong, even and fast rotation each time. The movement was accompanied by quite a loud noise caused by the internal mechanism which lasted until the machine was brought to a forced stop. Nothing suspicious was found.

"Finally, it should be noted that right at the start, before the machine was subjected to any testing, all rooms above, below and on either side were examined by the Commission. It was also verified that the stamps were not hollow, and no indication of any mechanism moved by a cord was found."

Another account by the District Magistrate, Johann Weise, confirmed other accounts, and added: "…the most extraordinary thing I noticed was that the machine showed the same strength and speed during the lifting and lowering of the load."

Professor Christian Wolff was also present. His credentials occupy a paragraph in Collins' book, but for the moment it is enough to mention that he was a pupil of Leibniz, member of the Royal Society, and scientific advisor to Peter the Great. A letter to Leibniz includes the following:

"…When the machine was ready to rotate, all adjacent rooms were opened and the bearings were completely uncovered. To prevent anyone accidentally seeing the internal structure of the machine, he covered it. Whilst he did this, he did not disguise the fact that the mechanism is moved by weights. Several such weights, wrapped in his handkerchief, he let us weigh in our hands to estimate their weight. They were judged to be about four pounds each, and their shape was definitely cylindrical.

"I conclude, not only from this but also from other circumstantial evidence, that the weights are attached to some moveable or elastic arms on the periphery of the wheel. During rotation, one can clearly hear the weights hitting against the wooden boards. I was able to observe these boards through a slit. They are slightly warped. When he put the wheel onto another support and reinstalled the weights in their previous positions, he pushed down on an iron spring that gave a loud noise as it expanded upwards. I therefore presume that there is no doubt that the wheel is moved by an internal source of power, but we cannot necessarily assume that it is perpetual. Furthermore, the machine may be of little value to the public unless it can be improved. At the moment it can lift a weight of sixty pounds, but to achieve this the pulley had to be reduced more than four times, making the lifting quite slow. The diameter of the wheel was about twelve feet, and as well, the bearing was quite thin, about one quarter of an inch and only a sixth of its length was subject to friction."

To control the crowds wanting to see the wheel, Orffyreus began requiring a small donation, which was given to the poor. His enemies used this as a ruse to have a tax imposed on Orffyreus. In a rage, he destroyed the Merseberg Wheel. He was offered the protection of Karl the Landgrave of Hesse-Kassel, and in 1716 he and his family moved to Weissenstein Castle. Karl was wealthy and powerful, an absolute ruler whose authority silenced Orffyreus' critics during Karl's lifetime.

Aside from Orffyreus' brother Gottfried, Karl was the only person of record to have seen the inside of the wheel, on condition of a payment of four thousand Thalers and an oath not to replicate it nor disclose its internal structure. Karl kept the agreement, but on occasion rebuked critics by stating that he has seen the mechanism and it was authentic, with no deception involved. Orffyreus was appointed Commercial Councillor, allowed the use of apartments in castle Weissenstein and a yearly salary of three hundred Thalers. Orffyreus built his fourth and last wheel.

In 1717, after the wheel had been in operation for three months and exhibited to people from many districts, Karl ordered that it be sealed in a room and left to run for two weeks. Karl set it in motion, and personally sealed the room. Two weeks later, Karl and his ministers verified that seals were intact, opened the room, found all intact and the wheel still running. Karl stopped the wheel, and restarted it. The room was sealed again, along with all windows and doors in adjoining areas. Six weeks later Karl found the seals intact, opened the room, and

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found the wheel in motion as he had left it. Karl issued a public certificate, wholly endorsing Orffyreus and the Wheel.

Orffyreus demanded 100,000 Thalers for his machine. There was no patent protection in that time. Apparently the mechanism was so simple that someone with the proper skills could replicate it after a short inspection. Orffyreus wanted to set up a school with the proceeds. Even though Peter the Great was interested in purchasing it, and could afford it easily, negotiations through intermediaries eventually came to nothing. After Karl's death, the attacks renewed and Orffyreus destroyed the fourth machine. He fell to his death in 1745.

Collins lays out in detail the attacks on Bessler/Orffyreus. These came primarily from a few men such as Gartner, Master-Modeller to the Elector of Saxony – a position of prestige, threatened by Orffyreus' accomplishment. Exposés were circulated, revealing the supposed fraudulent tricks, which bore no resemblance to the officially witnessed demonstrations. Then there was the absurd "confession" of a servant girl, who said the wheel (up to 700 lb in weight), was turned by oscillatory movement of a barbed wire, passed from a nearby room, acting on the axel. Orffyreus led a turbulent life, leading to bitterness and disappointment.

The story of how Bessler chose the name of Orffyreus is told in the context of the times. And there are the coded passages in his notes, which contain hints to the construction of the wheel, to which Collins adds other speculations about the nature of the mechanism. Altogether, Collin's book is a coherent, useful contribution to the history of anomalous energy research and the human tragedy that often touches the pioneers.

Comments on *Perpetual Motion*

by Thomas Phipps, Jr.

The bit of lost history revived in this book is most fascinating. We get a new perspective on Leibniz, Christian Wolff, Newton and other of their contemporaries...and throughout most of the book the author gives an apparently even-handed account of a real historical mystery: What was Bessler's wheel and how did it work? That was an age in which machines and elaborate mechanisms were just beginning to come into their own. The book deserves to be on many a history of science shelf, not only for the mechanical puzzle it poses but also for the timeless human story it tells of the fate of the lone inventor whose claims contradict received wisdom of the day.

I wish that the author had left off the last chapter in which he converts wishes to horses and rides off on them in all directions. Suddenly he has an Orffyrean chicken in every pot and all God's chillun possessed of 40 acres and a wheel. It's the ultimate Green dream: "Personally I believe that nuclear power generation has to go, and now that there is the *possibility* of producing electricity cheaply, without pollution, there is no need to wait any longer. All nuclear plant proposals should be cancelled and a start made on de-commissioning existing ones." I emphasized his word "possibility" here. We should start right now decommissioning the one source of comparatively nonpolluting electric power we have in order to capitalize on possible discovery of something even better. That's typical Green thinking, if I may say it: Discard your parachute and just jump from that ole airplane on the possibility that somebody will invent anti-gravity before you land. One looks for that kind of advice from children with flowers in their hair, but not from granddaddies, of which I gather Collins is one.

So, how possible is it? The author's enthusiasm is contagious, and I'll admit he had me discarding all I know, such as that gravity is a conservative force, and that gross mechanical devices are certainly ruled by the law of large numbers and by the second law of thermo. Mankind didn't begin to understand heat engines until thermodynamics was developed - for pretty much the specific purpose of dealing with the question of how close to perpetual motion it is practical to come. And the early investigators went about it in a fairly scientific way, in contrast to so much of what salutes that flag nowadays. As I say, he had me going .. . but I sat down and quickly convinced myself with some little diagrams that, if Orffyreus knew a way to extract more energy from a gravity field than he put into it, he knew a trick I will never know. Don't take my word for it (not that anybody would), try a little figuring yourself. But let's not waste too much time on this. The human species in aggregate has already paid a heavy toll to hopes of this kind. Reviving them just sets the clock back.

If there is anything in modern physics to encourage the old illusions of something for nothing (and here I am emphatically *not* talking about cold fusion, because that is a matter of something for something), I suggest it is not pointing toward extraction of energy from a gravity field. It must be extracting it out of the vacuum, which we have every reason now to believe is physically a plenum. I remember when I went to school there was passing mention of a *Klein effect*, whereby one produced a very strong electric field gradient and thereby tipped-up the Dirac negative-energy electronic "sea" so that it spilled over and made a mess on the carpet, or something - I forget. Anyway, the idea that the vacuum is full of negative energy certainly suggests that one way to gain "free" positive energy is to find some way to lose negative energy. I'd rather waste my dreams in that direction. But, no matter how heady they become, I hope I won't start confusing my "possibilities" with accomplished realities ... or recommending some political course of action that will sanctify my name among the so-numerous anti-scientific class of do-gooders.

INTERVIEW WITH JOHN COLLINS, Author of *PERPETUAL MOTION - An Ancient Mystery Solved?*

by Susan Seddon

John Collins says he has enough material to fill ten books about Johann Ernst Elias Bessler, a.k.a. Orffyreus. The one to which he (reluctantly) restricted himself took a year to write and was the culmination of over 30 years intensive investigation.

What inspired him to spend almost his entire adult life researching the eccentric deeds of a long-dead German inventor?

It was at the tender age of 15 that his interest was first piqued when he read "Mysteries" by R. R. Gould, which featured an account of Orffyreus and his amazing Perpetuum Mobile. To a teenager with engineering aspirations, the whole concept of unlimited energy was quite enthralling.

"Of course, I wanted it to be true," he said, "but there were so many loose ends in the story which just didn't tie in."

Years later, when in his 20's, and after gaining the hoped-for engineering qualifications, he came across the book again and his interest was reawakened: "Those anomalies still intrigued me," he said. "I just had to find out more."

John Collins

He found himself utilizing every spare minute of his

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leisure time in attempting to unearth the truth about Bessler and his wheel. A period of intensive research followed, starting at the British Museum Library where he discovered a microfiche copy of one of Bessler's original 18th century pamphlets. His first, and abiding, impression upon reading the translation was that Bessler's integrity shone through: "He believed in himself totally. I felt sure, from that moment, that he had been sincere and, if I was right, there was most definitely something worthy of further investigation here."

He wrote to libraries in Kassell and arranged to borrow a microfilm containing 600 documents concerning Bessler—all of these he photocopied, at considerable expense—eventually managing to get them all translated.

John Collins and his wife Sandra.

Most publishers were dubious about accepting his book: "Using the words 'perpetual motion' did me about as much good as it did Bessler," he said. He eventually decided to publish it himself.

To date he has sold over 4,000 copies, mainly via his highly-popular web site (http://www.free-energy.co.uk); [Note: The book is now available from Cold Fusion Technology, too - EFM]. His site scores 40-50 "hits" per day and, for a spell, he monitored access and was amazed to discover he'd had visitors from over 32 different countries (and, interestingly, also clocked brief forays by at least five different U.S. government agencies!)

Naturally, the implications of any new energy source would be of, at least, passing interest to world governments. His proposed PERMO device, if viable, could be a major breakthrough, especially in the Third World to drive water pumps and for generating electricity. But was the PERMO really practical in the average, modern 20th century home? "Absolutely," he said. "There is no reason for them to be enormous; the huge size was showmanship on Bessler's part. They can be run in series on one axle and, using modern technology and materials, they could operate in total silence and easily be miniaturized."

His only concern was that for power-hungry devices like electric cookers, the PERMO alone might not be able to sustain the required input level but, he believed, that coupled with output from PERMO energy-storage devices, there should be a way around that problem.

Had he ever attempted to replicate the wheel himself?

He smiled: "I've never stopped trying for the last 25 years."

He has made many models for his frequent lectures. The last one was 12 ft. in diameter to illustrate the scale of Bessler's last wheel and the problems which would be encountered should anyone attempt to remotely control such a monster.

He is currently actively engaged in building a working device, 18 inches in diameter and made from wood and plastic. He states that he's very close to full replication of the Bessler Wheel and is perhaps within three to four weeks of completing it.

"I know it can be done," he says, with the sort of quiet confidence which makes one feel that if anyone can do it, he can.

But he doesn't intend to replicate Bessler's attitude along with his wheel. There's no trace of Jed Rothwell's "Inventors disease" here. He intends to proclaim his discovery as loudly as possible, so that this energy source is in the public domain and available for use immediately.

John Collins has true empathy with the hardship suffered by Bessler towards the end of his life. His sadness that this amazing man died in abject poverty and despair clearly touches him deeply.

Although he didn't say the words, I believe he feels that offering this device to the world will be his personal and lasting tribute to the memory of Orffyreus.

John Collins has worked within the engineering industry for most of his 53 years. He has been employed by GEC and Rolls Royce Aero Engines and served five years in the RAF where he worked on the original Concorde. He once ran his own news agents shop which was, he says, a short-lived enterprise as he "spent all the takings." He returned to engineering and is currently UK Sales Manager for a steel company.

He has been married to Sandra for 29 years and they have two children and two grandchildren. They live in Leamington, about 16 miles from Shakespeare's birthplace, Stratford upon Avon.

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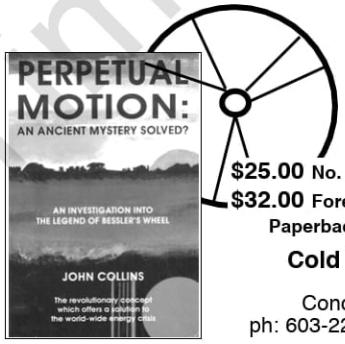

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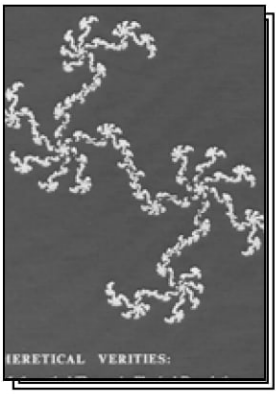

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Bessler's Wheel - An Explanation?

by Steve O'Donnell

After I mailed you my previous write-up on Bessler's Wheel, I decided that I had better get some experimental results to back my claims. So I stopped at a toy store and bought out their entire supply of toy magnets. These magnets have a very good ceramic magnet at one end, and a handle on the other. I then sliced off the handle, and ended up with a handy small rectangular magnet.

First I tried my magnetic induction theory. This was shot down in about five seconds. Electromagnetic induction works, but only with very intense magnetic fields, and very rapid movement (3600 RPM in the case of a standard induction motor). Using just a toy magnet, with big air gaps between the magnet and the conductor, coupled with the very slow speeds of Bessler's Wheel, and my fastest arm movement, I could produce no eddy current strong enough to move the lightest piece of aluminum foil.

Electromagnetically induced eddy currents do work in the case of the toy magnetically levitated top, because although these eddy currents are very tiny, the top is sitting on essentially a frictionless bearing, and so only very tiny amounts of force are needed to keep the top centered.

Scratch Theory One. If Bessler had tacked copper around his lightest wheel, and used the strongest permanent magnets he could find, he would not be able to move the wheel one inch, let alone try to move a 700 hundred pound wheel.

Then I started doing what Bessler must have done; I started to toy with my toy magnets. When a magnet was near any piece of iron or steel, I could feel with my fingers force acting across an air gap. The most intense force was generated between magnet and magnet, but I could produce almost as intense a force just between one magnet and a piece of iron or steel. My magnets allowed me to move a piece of steel over a distance of a couple of inches.

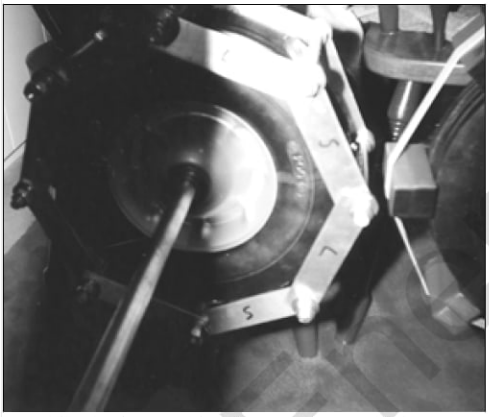
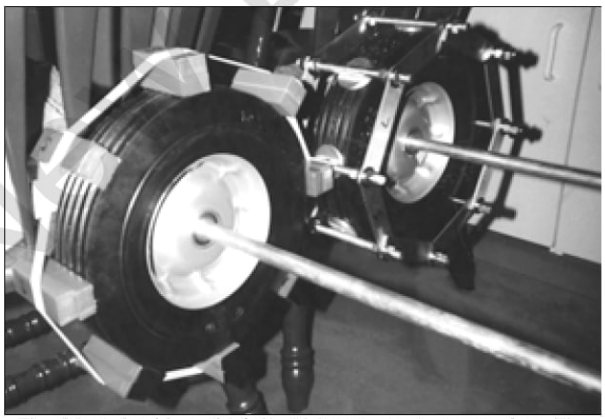


Photo showing the air gap between the two experimental wheels (Courtesy: Steve O' Donnell)

Could I use this powerful magnetic attractive force to drive a wheel across an air gap? So next I purchased two ten-inch general purpose wheels. The first set didn't work. The problem was the wheel bearings. They would slightly catch at places along the rotation. This made the wheel impossible to balance.



The drive wheel is to the left with toy magnets strapped on. The wheel driven is to the right. (Courtesy: Steve O' Donnell)

So I changed my wheel type from an inflation type, to one with solid rubber. This second type of wheel had much better bearings, and so it was possible to balance the wheel.

Next using rubber bands, I attached eight magnets to each wheel. I found I could use one wheel to drive the next wheel. In this demo, there was no electromagnetic induction at all, just pure magnetic attraction across an air gap.

I estimated that Bessler did not use this configuration, because it would require him to mount permanent magnets all around a 12-foot wheel. Instead he probably used only iron in the 12-foot display wheel, and used permanent magnets in the much smaller drive wheel.

So to simulate this configuration, I installed one wheel in a steel squirrel cage with eight round steel bars around the rim, connected on each side with eight rectangular steel bars. This simulates Bessler's public display wheel.

Next, using a rubber band around the other wheel, I mounted eight permanent magnets. This simulates Bessler's secret drive wheel. The picture shows 16 magnets, and this is because I doubled up the magnets in this configuration to increase the air gap.

Using a rubber band to attach magnets to the drive wheel makes it very easy to test lots of different configurations of magnets quickly. The drive wheel also has eight radial spokes stamped in the metal of the hub, so I used this to align the magnets by sight, when changing configurations. These magnets are marked "N" and "S" to easily recognize the poles. The pictures show the display wheel in its steel squirrel cage, and the drive wheel with its permanent magnet ring.

After building the squirrel cage, I had to decrease its radius slightly, to get a good friction fit with the underlying rubber wheel. I used two steel washers under each of the eight bars mounted across the wheel to decrease this radius. This is the purpose of the steel washers shown on the photographs. Each of these eight steel bars is cut from a threaded steel rod 3/8" in diameter. The ends were left exposed. The wheel was then balanced by adding additional nuts and washers to these exposed ends.

After all this was done, I didn't want to waste more time buying sawhorses to mount the wheels, so I just laid the wheel shafts between four chairs that were handy.

I can rotate the squirrel cage display wheel by manually rotating the permanent magnet drive wheel. The direction of this energy transfer is unilateral, and it only works one way, from the drive wheel to the display wheel. You cannot rotate the drive wheel by supplying power to the display wheel, even with an initial push to get it started. This is an immediate tip-off that there is something unusual about this unilateral energy transfer process.

The drive wheel is capable of starting the display wheel from a dead stop.

The display wheel can be driven in either direction. You can even start the display wheel in the clockwise direction, stop it by not turning the drive wheel, and then start the display wheel turning in the counterclockwise direction, with nobody touching it. This is very unusual behavior for a perpetual motion machine, so Bessler never displayed this feature to the local rubes.

Starting the display wheel from a dead stop is easy, but once it starts rotating, you must rotate the drive wheel so its magnets cross the display wheel with its transverse steel rods, just ahead

O'Donnell continues on page 69.

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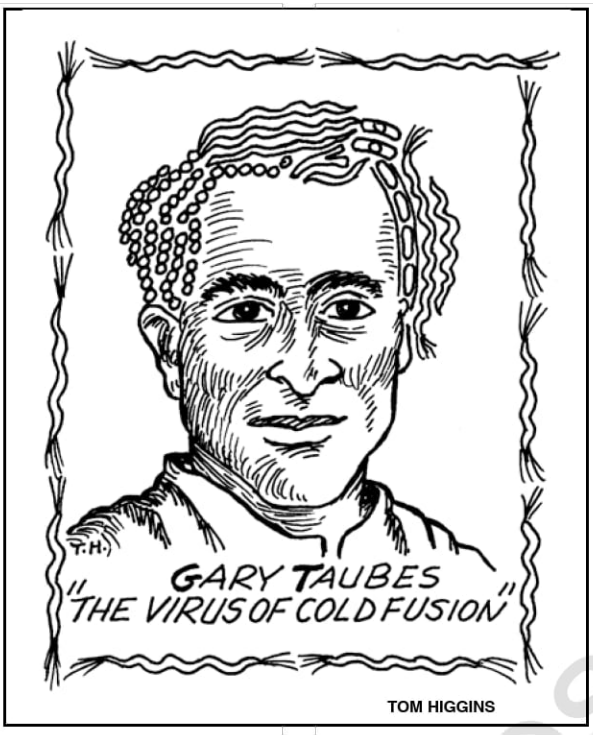
Cold Fusion Comix

— A variety of humorous insights about the serious matter of New Energy, New Physics, and Scientific



TOM HIGGINS

From:
MIT *Technology Review*,
May-June 1998, p.77,
by Gary Taubes

"The challenge for the science reporter is how to deal with the onslaught of fascinating—and quite likely erroneous—results. At times this chronic problem shows up in an acute episode like the infection known as cold fusion."

Technology Review's introduction of Taubes: "His great labor of love was a book called *Bad Science*— an excellent account of the fiasco known as cold fusion."

This is MIT's "Magazine of Innovation?" No, a joke fit for the *Comix* page!

BAR STOOL SCIENCE NO 2 - SOCRATES MUSES ON THE ETHICS OF LIMITLESS, FREE "FUEL" • BY SUSAN SEDDON

"Landlord, this isn't my bar bill, it's obviously intended for someone else. My name starts with an 'S' and this here is the digit '5.'" "Sorry, Mr Socrates, that's yours all right...50-crates of Turkish lager...that's your tab for this month." "This is quite hideous.....how much!!!" "That's the market price these days...this is 400 B.C. you know, mate." "Well, it's a travesty, that's all I can say. Damned inflation! My old mate Hippocrates was complaining only yesterday about the price of wine...and he swears on his oath that he only uses it for medicinal purposes too. There ought to be a way of making it out of later....that'd put you leeches out of business for sure. Now, I suspect there might be a way of doing this...I've had a theory for some time...I was going to write it down but then, why break the habit of a lifetime? I think if I could raise the temperature of some water in a psykter... I had a notion to put some metallic thingies in there too for some reason, can't quite recall why...anyway, I think there could be an interesting reaction. I'm unclear what I'd call this reaction...possibly an anagram of 'unclear' as that's how I seem to be on most things these days. I reckon with a little practice I could turn the water into 100% proof." "Yeah, well you'd have the breweries round your neck, for sure." "That's the idea. To render the breweries completely redundant...surplus to requirements....why pay for wine when you can get it for nothing. It'd be too cheap to meter. They'd go bust." "You'd create chaos, the global economy would collapse and what about the effect on greenhouses? Industrial-scale viticulture would cease...no more vine nurseries." "Serves the wine-makers right for being so greedy and monopolising the market. Free wine is the fundamental right of every human, not a privilege merely for those who can afford it." "I'd keep your voice down, if I were you, mate. There's a lot of vested interest in the booze market." "Oh yeah... I'm shaking in my sandals. What do you think they'd do...poison me? Anyway, one thing's for sure, I'm not paying for this crate of lager, it's disgusting...tastes like hemlock." [Next issue... Charles Darwin raids "The Beagle's" rum locker and expounds on Artificial Intelligence]

Send your humorous quotes or art to: Cold Fusion Technology, Managing Editor, P.O. Box 2816, Concord, NH 03302-2816

"The existence of atoms is itself an hypothesis and not a probable one. All dogmatic assertion upon it is to be regarded with distrust."

*Charles William Eliot, 1868 Teacher of Chemistry,—eventual President of Harvard University **

Amedeo Avogadro postulated that "*Equal volumes of all gases* under the same conditions of temperature and pressure contain the *same number of molecules*." "When his classic paper on molecules was published in 1811 **not a single scientist of the world commented upon it.**" Not a word of eulogy was pronounced at his death. One hundred years later an historic meeting took place to commemorate the hundredth anniversary of the publication of Avogadro's classic memoir. His theory resulted in strides that were made in the study of the molecular composition of the most complex chemical compounds.*

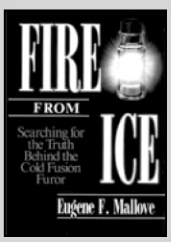
*Historical information taken from "Crucibles: The Story of Chemistry" by Bernard Jaffe

FIRE FROM ICE:

Searching for the Truth Behind the Cold Fusion Furor

By Eugene F. Mallove, Sc.D.
Published by John Wiley & Sons, Inc., 1991, 334 pp.
$25.95 No. America; $29.95 Other Foreign

A timeless treatment of the greatest scientific drama of our age. Nominated for a Pulitzer Prize in 1991.



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Words to Eat...

"If those University of Utah chemists who thought they had discovered cold fusion in 1989 had understood Faraday's law of electrolysis better, perhaps they would never have embarrassed themselves as well as the rest of us."

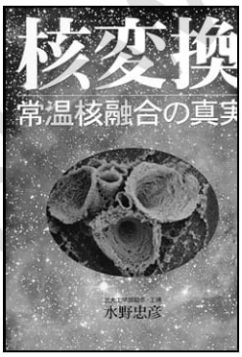
in *The God Particle: If the Universe Is the Answer, What is the Question*, (p.122-123) by Leon Lederman with Dick Teresi, 1993, Houghton Mifflin Company

Physics Nobel Laureate Leon Lederman
(Photo: Courtesy, Fermilab Visual Media Services)

We are happy to bring to light this idiotic comment by the amiable Nobel Laureate Leon Lederman. Lederman has been in the news for his politicking about the need for improved science education. I suggest that he start by learning himself one of the basic foundations of science: the primacy of new, validated experimental data over pre-existing theory.

There can be no more embarrassing a phenomenon than a scientist, such as Lederman, who pontificates about a subject in which he or she knows virtually nothing. Lederman apparently has absorbed his cold fusion information from wayward "authorities," such as ignorant journalists and self-interested scientists who themselves have expounded falsely and unethically about a new class of scientific observations.

—Eugene Mallove



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Bass continued from page 49

$M_5 = [\exp(ik.[L+1]), \exp(-ik.[L+1]); ik.\exp(ik.[L+1]), -ik.\exp(-ik.[L+1])]$,

$M_6 = [\exp(\kappa.[L+1]), \exp(-\kappa.[L+1]); \kappa.\exp(\kappa.[L+1]), -\kappa.\exp(-\kappa[L+1])]$,

$M_7 = [\exp(\kappa[L+2l]), \exp(-\kappa[L+2l]); \kappa.\exp(\kappa[L+2l]), -\kappa.\exp(-\kappa[L+2l])]$,

$M_8 = [0, \exp(-ik[L+2l]); 0, -ik.\exp(-ik[L+2l])]$,

$c^1 = Mc^5, \qquad M = \Pi_1^7\{M_j^{-1} M_{j+1}\}$,

where in the repeated matrix-product only odd values of j are allowed. The wave in the *region V* is to be purely a transmitted, right-traveling wave, so that $c^5 = [0, 1]'$. Hence c^1 is well-defined and determined uniquely. After scores of pages of tedious algebra, one finds a closed-form solution for b_1 which must be set equal to unity if complete resonant transmission through both barriers is to be achieved. Separating the real and imaginary components of this complex equation, one obtains, finally $\tan(k.L) = -\tan(\beta)$,

where β is a function only of (k, κ, l) but not L. Accordingly, $k.L = \beta + (4n+1)(\pi/2)$, whence, finally, recalling the definition of k,

$$L = Lo + (4n+1)(\lambda/4)$$

as claimed.

COROLLARY. If the well-width L is fixed, then the Spectrum of Energy Levels corresponding to resonant transparency is given by

$$E_n = E_o.(4n+1)^2, \quad (n = 1, 2, 3, \ldots),$$

where $E_o = \{[h/(L - L_o)]^2\}/(32M)$.

Dr. Robert W. Bass, *Infinite Energy's* expert on theoretical aspects of cold fusion and low energy nuclear reactions, is an internationally-recognized inventor and former Professor of Physics and Astronomy (BYU, 1971-81, retired). He has served on the faculties of Aerospace Engineering Sciences (Univ. of Colorado), Electrical Engineering (UCLA), and Aero Engineering (Egyptian Air Academy). In addition to seminal issued Patents, he has over 40 years experience in university teaching, research, and in industrial R&D in the areas of modeling, analysis, computer simulation, empirical parameter-identification (**PID**), and control algorithm development for aerospace vehicles and other complex dynamic systems, such as fusion plasmas. His education: Postdoctoral, Princeton University, 1955-56 and 1957-59; Ph.D. (Mathematics), Johns Hopkins University, 1955; M.A. Oxon (Maths), Oxford Univ. [Rhodes Scholar], 1952; B.A. (Physics), Johns Hopkins University, 1950.

Dr. Bass has been internationally recognized since 1960 as one of the founders of Modern Control Theory. In recognition of this fact, the 1998 **American Control Conference (ACC)** [formerly Joint ACC of the aerospace, electrical, chemical and mechanical engineering societies], scheduled a **Special Session** in honor of the seminal contributions of Bass to control and filtering technology, entitled "The Influence of Bob Bass in Mathematical System Theory," to which a half-dozen of the world's most renowned control and filter experts submitted papers for presentation at the ACC in Philadelphia (June, 1998).

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A Review and Commentary by Jed Rothwell on

Power Surge—Guide to the Coming Energy Revolution

(Christopher Flavin and Nicholas Lenssen, Norton, 1994)
ISBN #0-393-31199-6 $10.95 U.S. $13.99 CAN

This is a lively, well-written introduction to energy as it impacts society and ecology, written from a staunchly environmentalist viewpoint. Flavin is the head of energy research at Worldwatch, and this book is part of "The Worldwatch Environmental Alert Series." Despite its partisan point of view, I find it reasonably objective. An essay published by the Cato Institute in opposition to environmentalism cites this book as an authoritative source of information, and finds more common ground than one might expect.[1] In the five years since the book was published, it has become clear that some of its predictions of progress in alternative energy were too optimistic, and the predictions of environmental damage and rising fossil fuel energy costs were too pessimistic and alarmist.

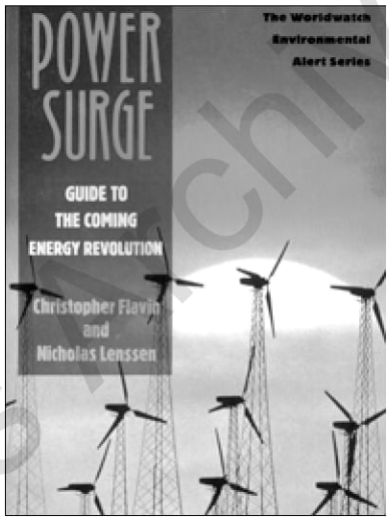
Flavin and Lenssen think that conventional, renewable alternative energy sources like solar and wind will eventually replace fossil fuel and nuclear fission, benefiting the ecology and the economy, making the world a cleaner and happier place. They do not consider clean energy a panacea. They realize the dangers of over population, pollution, and the misuse of land in agriculture. But they regard energy as one of the biggest environmental problems and the root cause of many others. If I did not believe cold fusion is viable, I would agree with this book, but cold fusion will make most of it moot. It is still a thought-provoking look at how innovation might change the energy market. In a letter to the authors I wrote:

> We anticipate a sudden, *deos ex machina* happy ending to the energy crisis; a technological tour de force. We think the problems described in your book will abruptly vanish, the way polio vanished from industrial society after Salk and Sabin. If cold fusion can be made practical, it will quickly give rise to the kinds of technology you describe, especially decentralized power generation, mass-produced small devices, and technology driven progress.[2]

The book stresses the importance of energy efficient devices like compact fluorescent lightbulbs and well-insulated buildings, which let us have our cake and eat it too. The authors express some fears about future catastrophes caused by pollution and global warming, but in general they are upbeat and constructive. They conclude that progress in energy innovation is accelerating, and that future progress will be driven by technology rather than the politics and wars that set the price of energy during the oil age:

> As experts consider the future of the energy economy, they may learn more by studying the electronics revolution of the late twentieth century than by applying the geopolitical and geophysical framework of conventional energy analysis.

Power Surge is a short book without extensive technical detail. Other reference books, textbooks and a special issue of *Scientific American* are more comprehensive.[3,4,5] But this book has good statistics, tables, and well-written, concise descriptions of many important energy issues. It describes most major energy issues adequately, except one: it includes little discussion of energy use by industry, which is about one-third of U.S. consumption.[6] The book has copious footnotes; most assertions are documented from authoritative sources, like Exxon and EPRI. It is a handy place to look up things like efficiency of lighting: lumens per watt for candles, incandescent, and fluorescent lights, from research at the World Bank.[7] Many personal communications from experts are cited, which is a good sign. The authors went beyond the textbooks and asked the experts directly. The book describes some topics in detail including cogeneration, natural gas, and the electric hybrid automobile, which the authors and I consider a promising and important energy innovation. Readers unfamiliar with hybrid autos will learn a lot about them in a short space of time.



The authors express controversial opinions, but these opinions are backed up with an impressive array of facts and statistics. Where the scientific evidence is not overwhelming, they point out weaknesses in their own arguments. For example, they make no secret of the fact that they think global warming from carbon dioxide is a real threat, but they say some scientists disagree. They include enough temperature data to make a credible case, and they say: "The lack of certainty is hardly a reason for complacency . . . The nature of the climate problem – with its long time lags, irreversibility over hundreds of years, and potentially catastrophic effects—argues for caution." They emphasize that the steps we take to reduce the threat of global warming will have other, positive benefits. This is the main point of the book: reducing energy consumption is good for you, it feels good, and it saves money in the long term while creating jobs today.

Despite the subtitle, this book is not a guide to "The Coming Energy Revolution." It is not revolutionary. It is conventional, conservative, and timid. The book is not about the future; it is about the recent past, and a guide to what might have been were it not for cold fusion. The changes described here would be based on prosaic, conventional technology: all chemical and

The book is divided into four sections:

"I. Pressure for Change"—covers the history of industrial energy, the oil shocks, the threat to ecology from pollution and global warming.

"II. The New Power Brokers"—Conservation, the use of natural gas in place of oil and coal, wind, solar heating, solar generated electricity, and biomass.

"III. Energy in Society"—the major uses of energy in transportation, houses and buildings, and the need to restructure the electric power industry. The use of energy in industry is not covered, which is a strange omission. The restructuring of the fossil fuel industry is not discussed. Perhaps the authors believe, as I do, that no restructuring is possible, there will be no role for these industries, and they vanish like the horse-and-buggy and slide-rule manufacturers.

"IV. Energy Futures"—the authors' prognostications about the future of energy, a dire scenario for possible global warming, and a summing up of previous chapters.

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solar, not nuclear fission or fusion. The authors dismiss fission, the hot fusion program and high tech concepts like solar power concentrated by satellites and beamed to earth. They extrapolate continued progress and falling prices for things like photovoltaic chips and windmills. They predict more widespread use of efficient lighting and building construction, and they come to a logical conclusion: the energy crisis can be solved and pollution from energy can be largely eliminated using existing technology. We do not need exotic, futuristic energy systems like the aforementioned giant satellites, or Tokamak fusion reactors, or cold fusion. I agree, but it will cost a terrific amount of money to solve the energy crisis with the kind of technology Flavin and Lenssen advocate, whereas with cold fusion it will cost nothing. Actually, it will cost less than nothing: cold fusion automobiles and toasters will be cheaper than today's models, whereas a lightweight, complex, high tech electric hybrid automobile is bound to cost more than a simple gasoline powered model.

The solutions the authors advocate would be expensive because they are complex and must be built on a massive scale in the aggregate. They advocate things like rooftop solar collectors augmented by electric power and gas distribution networks, with unused power from some houses channeled to others over the grid. This would double the burden of hardware maintenance and it would complicate electric company billing. The authors regard this extra work as an advantage. They talk about the "host of economic opportunities" we will create by solving the energy crisis. If we must solve the energy crisis by conventional means, then I agree we should get on with the job, even if it costs a lot of money and effort. But if cold fusion is available it would be absurd to waste money on labor-intensive conventional systems. Flavin, Lenssen and others in the environmental movement would consider this heresy, but I say the same for advanced light water moderated fission reactors. If we can make them work safely, reliably, and economically, and we find a safe method to store the waste, I think these reactors may have less of an impact on the environment and cause less pollution and solid waste than alternatives like photovoltaic cells, windmills and other sources of renewable energy. These renewable sources have low power density, so they require gigantic collection systems spread out over hundreds of square kilometers. They would require a mountain of manufactured articles as large as our fleets of automobiles. The equipment would wear out and it would have to be recycled and replaced, causing a terrific solid waste disposal problem. Nuclear energy (whether conventional or cold fusion) is a million times more compact; it requires less infrastructure and manufacturing and the generating plants take up practically no space. However, nuclear and fossil fuel systems both take up more space than the actual plants alone; they also take land mines and strip mines. As Flavin and Lenssen point out, this land is permanently ruined, whereas after you scrap a solar or windmill array, the land under it remains intact. Cold fusion will not require any mines, strip mines, or large arrays of equipment.

Flavin and Lenssen often talk about electronics and other "revolutionary" technologies and how they can spur advances in energy. Computer controls make hybrid electric vehicles easier to engineer and more practical; electronic controls adjust windmill motors for maximum efficiency. The authors seem to forget that improved electronics also enhance the extraction and refinement of fossil fuels and the efficiency of internal combustion engines. In oil drilling, for example, supercomputers have improved geological survey techniques which have reduced the number of dry holes. In oil fields, computers allow sophisticated sideways drilling techniques. So far, fossil fuels seem to be winning the technology race, dropping in price faster than renewables. Historically, improvements in technology have often spurred overall progress, but sometimes they have retarded it. New technology can cause social change, or it can prop up obsolescent industries and reinforce out-moded social customs. Scientific advances in ship design, and iron and steel hulls benefited sailing ships as much as they helped steam ships. They ushered in the golden age of clipper ships, which may have prolonged the use of sails.

The authors also look to electronics as a development model, in which prices fall, production increases and capabilities improve at a fantastic rate. Computers change so rapidly, that the value of completed inventory falls by 1% per week. Such rapid change has its drawbacks. Thomas and Post at Sandia National Laboratory found that the inverters and other peripheral equipment in photovoltaic equipment also changes rapidly, with models becoming obsolete soon after they are introduced.[8] This makes long term product evaluation difficult. Thomas and Post describe other qualities reminiscent of the computer business: 10 to 30% of the inverters fail to work upon delivery; warranty periods are short; and the photovoltaic chips seldom work as well as the manufacturers claim.

Alternative energy has not fallen in price or improved in performance as rapidly as computers and I think it is unreasonable to expect it will. Computers have an unfair advantage: they do no useful physical work, so you can make them as small as you like. People often say that if automobiles had progressed as quickly as computers, cars would cost a penny each by now. A frustrated automobile company executive once responded: "Yeah, I could make a million tiny cars for a penny each, but what good would they do? Photovoltaic panels and windmills do real work. You cannot shrink them to microscopic size.

Flavin and Lenssen envision a commercial and cultural revolution, not a technological one. Despite the lip service they pay to the importance of technology, most of the examples they cite are not breakthroughs in science or technology, but rather incremental improvements in manufacturing, like Ford's gradual reductions in the price of the Model T and the falling cost of integrated electronics. They include the famous graph of Model T price versus production. This example is too old. Photovoltaic chips, inverters and windmills are already manufactured on production lines. Many advantages of scale and automation have already been achieved. Ultra-large scale production lines, like the Ford Model T Rouge River plant, have been obsolete for decades. Modern lines are lean, "just-in-time," flexible and adaptable. Since inverters and generators change as rapidly as VCRs, windmill production lines will have to be as flexible as any.

Flavin and Lenssen do not talk about fundamental scientific progress in energy and they do not appear to think it is necessary. They dismiss the hot fusion program. They say that fission is an uneconomical dead-end technology, doomed by safety concerns and cost overruns. Their attitude toward progress reminds me of recent books like *The End of History and the Last Man* by Francis Fukuyama (Avon Books, 1993) and *The End of Science: Facing the Limits of Knowledge in the Twilight of the Scientific Age* by John Horgan, editor of *Scientific American* (Helix Books, 1997). These books assert that technological and social progress has slowed down, that fundamental, seminal discoveries have all been made, manned exploration of the planets will never be worthwhile, and problems like energy, pollution, and cancer can be reduced or finessed mainly by legislation and bureaucratic controls, but not solved at a single stroke by an unforseen breakthrough. Horgan and other *Scientific American* editors are hostile toward cold fusion.[9,10]

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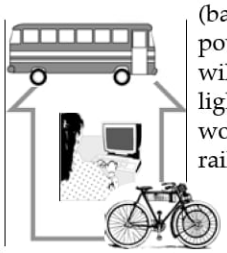
Flavin and Lenssen make one brief mention of cold fusion. In the concluding chapter they present an optimistic scenario in which carbon dioxide declines and renewable energy blossoms:

> This scenario is based on the assumption that governments would rationally but aggressively pursue the technologies and policies discussed in earlier chapters. No breakthroughs in cold fusion or government takeovers of the energy sector are considered. Indeed, we believe that our "sustainable future" will unfold most rapidly in market-based economies, although governments will need to reverse many of today's energy subsidies.

Incremental Versus Radical Solutions

In general, there are two approaches to improving technology: incremental and radical. You save energy with incremental adjustments that improve existing techniques, and by radical changes that do away with the task, eliminating energy consumption completely. For example, in manufacturing, you might incrementally improve the efficiency of a milling machine. Or you might redesign a product and manufacture it in one piece, in the exact size and shape you need, so that it does not have to be milled. You can save energy by improving a furnace, but you might save even more by recycling scrap.[11] Both incremental and radical innovations are needed. I think this book shortchanges the latter. The authors talk about the advantages of mass transit and bicycles, but they pay little attention to new, high tech alternatives to commuting. They devote only one short paragraph to telecommuting. Americans are hardly likely to start riding bicycles in large numbers, and they will not put up with the delays and inconvenience of riding buses. Twenty-first century American consumers will not embrace nineteenth century mass transit. But corporations may decentralize, developing home and satellite offices linked by the Internet. Enormous improvements in communications speed and capacity (bandwidth) may follow, like large, low-power, high-resolution video displays, which will substitute for wallpaper and overhead lighting. Together, these two innovations would transform telecommuting as much as railroads transformed travel. Telecommuting will be easier, cheaper and more practical than physical commuting. The authors of this book know a lot about energy. Perhaps they know too much, and they focus too tightly on energy engineering solutions to energy problems—the direct approach. Some of these problems are best circumvented by inventions unrelated to energy, like telecommuting.



Let us look more closely at telecommuting to see how it compares to the energy engineering solutions. Telecommuting has so far had little impact on energy use or traffic congestion. Most people who telecommute are writers, salesmen and others who have traditionally worked outside centralized offices. A civil engineering professor who has studied telecommuting concluded that so far it has had no impact and it may have actually increased driving for some workers.[12] I think this is because our present telecommunications are inadequate. Telecommuting will be revolutionized by the high bandwidth "super Internet" now being tested by government and university laboratories. Low powered LCD displays developed for laptops are now being sold for desktop computers. They will eventually evolve into high-resolution, large, thin, low-power screens. With these two innovations your home or satellite office would have a "video window" into the main office, or anyplace else you want to see. When you arrive in the morning you will set up an audio and video link and leave it in place all day. You will look up from your desk and see into your co-worker's office, which might be a thousand kilometers away. These innovations will give managers and co-workers nearly as much immediate, personal contact as they have today in a physical office. They will eliminate the biggest complaints about telecommuting: isolation, confusion from being out of touch, and the inability to hold a quick conversation about a problem or suggestion. A manager or colleague will be able to "walk into" an office to consult, or gather people for a meeting instantaneously. The focus of attention at a meeting is usually on a speaker or an object: the blackboard, the physical evidence gathered at the crime site, the x-rays, or the widget the customer sent back. In future video meetings the speaker or widget will be displayed at full scale and high resolution, close enough for everyone to see. In evening news broadcasts today, interviews and panel discussions are conducted by people scattered in different cities, who watch one another on video. In the future, everyone will be able to do this, for less money than it costs to physically commute. Riding a bus or improving Carnot efficiency can only reduce energy within limits, with diminishing returns. If we could persuade most commuters to ride the bus, and by heroic methods improve the Carnot efficiency of motors from 15% to 80%, we would reach the limits of these incremental improvements. It is difficult to project how much this would reduce energy consumption, but it could not be more a factor of ten improvement over present day energy use per passenger mile. This optimization would do nothing to reduce travel overall; it would make passenger miles cheaper, but it would not reduce them. On the contrary, more efficient vehicles will cost less per passenger mile and encourage more commuting. In contrast, when most people telecommute or walk to a satellite office, we might reduce commuting energy consumption a hundred-thousand fold, and as a side benefit eliminate traffic jams, parking problems, and the time wasted in commuting.

The technology I have sketched may seem expensive and futuristic, but it is not. Private investments in Internet improvements are booming and progress is swift. Super-fast Internet is closer to implementation than most of the "blue sky" alternative energy schemes Flavin and Lenssen describe. It will be cheaper and less environmentally disruptive. It is the difference between laying a fiber optic cable and building a new subway.

Cogeneration

Flavin and Lenssen discuss large co-generators for factories and buildings, but they do not say much about small gas-fired co-generators for home use. This is strange, because they are enthusiastic about other small, distributed sources like solar, wind, biomass and so on. The advantages of distributed co-generators are easy to understand. Centralized electric power generators throw away 64% of the energy from fuel as waste heat; only 36% is converted to electricity. Eight percent of this electric power is lost in transmission over the power distribution grid.[13] In winter, a co-generator in your house would heat the building instead of throwing away the waste heat, and it would eliminate the transmission losses. The disadvantages are that small generators are expensive, unreliable, inefficient, and they create more pollution than centralized generators. Recent improvements in miniature gas turbines might make home cogeneration cheaper than other sources of electricity.[14] These turbines are a spinoff of research in jet airplane engines, which are extremely efficient. Larger "aeroderivative" generators are based on the DC-10 airplane engine. They produce 50 megawatts at 39% efficiency, and they may approach 60% efficiency in a few years.[15]

Some Disagreements

I did not catch significant factual errors in this book. The statistics come from authoritative sources like EPRI, the DoE, the

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JPL, and specialized engineering firms. However, tables of statistics must be carefully interpreted and many are open to question, as I show in the example below ("Case Study: Photovoltaics"). Even the most authoritative sources have wide variations. For example, electricity lost as waste heat in the grid (the energy lost between the power plant and the customers) is variously quoted in the literature as 8 to 13%. I usually take 8%, which comes from a 1990 Pacific Gas and Electric study for a 500 mile transmission. Obviously nobody knows exactly how much is lost, and losses will vary from one power company to another, depending on how far from the city the power plant is located, how new the high tension power lines are, and a host of other factors. When two authoritative sources agree exactly, you will usually find they borrowed the numbers from the same study.

This book has many projections of future developments. Such projections and plans must be made, but they are never right. Even the best ones veer off after a few years. An energy study from 1990 is useful for its data circa 1990; the future projections in it are only good for teaching the futility of making predictions. I agree with Freeman Dyson's rule of thumb that no large engineering project should take longer than five years before it begins to pay off, or it will be obsolete before it is finished.[16]

Although I did not catch factual errors, I did see errors of judgement and unwarranted conclusions, like this one:

> The transition to a hydrogen energy system raises other important questions. We currently depend upon large quantities of petrochemicals—used in everything from fertilizers to cleaning fluids and clothing. These carbon-based materials are derived from various oil by-products that flow in enormous quantity from the world's refineries. If oil is abandoned, we will need another source . . .

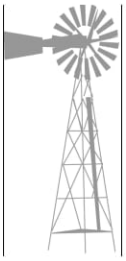
Even if we do stop using oil for energy, why would we stop using it for petrochemical feedstock? What would be the point? Fertilizers and clothing do not pollute the air or threaten global warming. Why wouldn't we cut oil production 86% and use the remaining oil exclusively for non-energy applications?[17] The authors seem to believe that we can only use a fraction of the oil for feedstock. Feedstock can only be a "byproduct," and we cannot divert 100% of oil production into feedstock. That is incorrect. I predict that we will continue to use oil, coal and natural gas for chemical feedstock until it becomes cheaper to synthesize hydrocarbons from air and water with cold fusion energy.

The most confusing and contradictory portions of the book concern the electric power grid and the "small versus large" and "appropriate technology" arguments popularized by E. F. Schumacher and A. Lovins. I think the "small" versus "large" distinction is a false dichotomy. Small, decentralized technology like computers and photovoltaic cells depend upon giant centralized high-tech factories. The hypothesis has other weaknesses. It springs from an overly romantic view of the past and misguided hostility toward technology and centralized, large corporations. Choosing the best energy source is an immensely complicated problem. Consumers, power companies, and politicians must work together to balance safety, pollution and cost concerns. Lovins simplifies by picking the *smallest* generator, despite the fact that small automobile engines, wood stoves and generators are notoriously the worst polluters and the least efficient. The weaknesses of distributed power are described in a brilliant essay by Samuel C. Florman, "Small is Dubious":[18]

> Whatever the advantages of this concept (and Lovins's technical calculations have been challenged by a host of experts), its widescale adoption would obviously entail the manufacture, transport, and installation of millions of new mechanisms. This cannot but be a monumental industrial undertaking requiring enormous outlays of capital and energy . . .

Florman himself is a little confused about the issue of scale. He goes on to say:

> . . . Then these mechanisms would have to be maintained.



> We all resent the electric and phone companies but, when service is interrupted, a competent crew arrives on the scene to set things right. It is easy to say that the solar collectors or windmills in our homes will be serviced by our independent neighborhood mechanic, but this is a prospect that must chill the blood of anyone who has ever had to have a car repaired or tried to get a plumber in an emergency.

Small equipment does not have to be sold or serviced by small companies. Sears will service your automobile, furnace, or air conditioner. Electric company repair people will fix the transformers outside your house. In the future they may come indoors to fix a generator in your basement.

With solar energy the power distribution grid would still be needed, because on rainy days you would have to borrow electricity. With gas cogeneration or cold fusion you would buy enough capacity for your needs, and we would do away with the grid. This would save a terrific amount of maintenance expense and energy wasted in transmission. Some people have expressed concern that with cold fusion we might use so much energy, we heat the atmosphere and hurt the environment. Actually, the immediate prospect for the first decades with cold fusion would be that we reduce conventional energy consumption with co-generators at home and better Carnot efficiency in automobiles. We might make up the difference and use more energy overall with something like a massive desalination project to convert African and Asian deserts into jungles and forests, but this would enhance the environment and reduce carbon dioxide and the threat of global warming.

Politics

This book favors capitalist, free market approaches. It repudiates the politics of 1970s-style environmentalism. It describes the California zero emissions vehicle law (ZEV) as inflexible and unhelpful because it prevents practical, close-to-zero pollution innovations like hybrid electric automobiles. The authors are strongly committed environmentalists but they repudiate the school of conservation symbolized by President Carter's sweater and his talk of national malaise. The last thing we want the public to think is that conservation is cod liver oil—something you hate, which probably does no good, but which the National Nanny insists you must swallow anyway. Clinton has a better approach, describing conservation as a glamorous, upbeat "win-win" technological marvel. The message is we can do more with less and save money. We can have our cake and eat it too. Americans love sparkling new technology. The authors maintain an upbeat outlook, yet they do not sugarcoat the seriousness of present day pollution and the potential for disaster in the future. They reveal the pessimism of the anti-environmental industrialists. In a refreshing role reversal, governments and corporations say we cannot fix these problems, while the environmentalists take the lead with can-do, pro-technology, positive thinking. Flavin and Lenssen have this to say about the World Energy Council, a mainstream organization funded in 1923 which works with the U.N., the World Bank and other heavyweight organizations: [19]

> . . . the World Energy Council [WEC] envision the basic outlines of today's energy systems remaining unchanged for decades . . .

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This mischaracterization [by the WEC] of its own results is symptomatic of the problems with most such studies. Although the assumptions used have evolved somewhat since the mid-seventies – projections made then now appear ridiculous – they continue to lag behind changes in the real world. Among the blinders that skew all the WEC scenarios are extensive analysis of fossil fuel reserves but no quantitative estimation of renewable resources; the lack of a detailed assessment of energy-using appliances and industrial equipment; extensive discussion of the pros and cons of nuclear power but hardly a mention of solar photovoltaics or fuel cells and the assumptions that technological advancement will proceed slower in the future and that developing countries will continue to lag far behind the industrial world in both economic and environmental development.

Many of these assumptions seem dubious; others are frankly implausible. Overall, they paint a misleadingly gloomy picture of the potential to forge a more sustainable energy economy in the decades ahead. Sadly, they are the same assumptions used by most governments and by organizations such as the International Energy Agency.

The authors give environmentalists, especially Lovins, a great deal of credit for improvements in energy efficiency. In 1976 Lovins wrote an article in Foreign Affairs which "sharply challenged some of the most fundamental assumptions used by energy planners, including the sacred principle of endless growth," and the iron link between energy use and the size of the economy. The authors regard this as a watershed event. They say it triggered a storm of opposition, including 2,000 pages of testimony and letters in Congress from big guns like Hans Bethe and a General Electric vice president, who called Lovins' vision an "energy Shangri-la." Others called Lovins an "energy amateur" and a "purveyor of naked nonsense" that would lead to a "New Dark Age." The authors portray Lovins infuriating automotive engineers by telling them that cars get only 15% Carnot efficiency and they ought to do better. He challenged them to use innovative new technologies to make an 80-mpg "supercar."

Given the events surrounding cold fusion, I can well believe these people were upset by Lovins and they published 2,000 pages of invective in the Congressional Record. But I do not think they were ignorant of physics. They understood thermodynamics. They knew, or should have known, that the 80-mpg car can be built. I think these experts, and Lovins – and the authors of this book for that matter – do not understand industrial history and economics. Energy efficiency has been increasing steadily from the beginning of the industrial revolution. There was no reason to think it had peaked in 1976. We were far from the thermodynamic limits (the limits of Carnot efficiency). And there are many ways to go beyond these limits, such as the example described above, in which a metal part is manufactured to specification so that it does not require additional energy-intensive milling. Japanese and European industry were much more energy efficient than the U.S. in 1976. This was common knowledge: it was discussed in newspapers and magazines, and it was clear to people visiting overseas. When the energy crisis hit in the late 1970s, everyone should have known we would soon find easy ways to save energy, first by learning from Japan and Europe. We did not begin working on the energy problem earlier because fuel was cheap, there was no economic incentive to improve, and pollution laws were lax. Money spent elsewhere produced a larger return on investment. Lovins deserves credit for pointing out the inefficiencies, but OPEC gets the credit for reducing them. The experts did not learn about the potential for improvement from Lovins. Any automotive engineer knew that automobile internal combustion engines were only 15% efficient and other types would be better. They must have known about hybrid vehicles. The first hybrid automobile was patented in November 1905.[20] Hybrid diesel electric railroad locomotives were first built in the 1930s and have been the dominant type in North America since the 1950s. Perhaps the engineers who opposed Lovins argued that hybrid automobiles (or some other alternative) would cost too much to manufacture, or that they would be too complicated and require too much maintenance, or driving performance would not satisfy customers. But they would have known that a hybrid can double or triple gas mileage, and Hans Bethe *should* have known. It has been common knowledge for nearly a century.

A Case Study: Photovoltaics

This book was written five years ago. It projects a great deal of progress which, unfortunately, has not been realized. Alternative energy prices have not fallen. Megawatt hours have not risen exponentially. Alternatives have not swept the market. I investigated one of the alternatives described in detail: the photovoltaic cell. I discovered a number of pitfalls not discussed in the book. In a chapter devoted to this topic, the authors begin by discussing photovoltaics in the third world:

It is hard not to be struck by the irony that the basic energy needs of some of the world's poorest people are being met by what is arguably the most elegant and sophisticated energy technology yet developed.

I see nothing ironic in this, and I suspect that people who do see irony are unfamiliar with life in the third world, where radios and motorcycles are essential to survival.

Photovoltaics are indeed elegant, sophisticated, high tech, solid state devices, similar in many ways to cold fusion cathodes. We can learn important lessons from the failures—and limited success—of photovoltaics. Five years ago I hoped that by now we would have a cold fusion demonstration automobile, or at least a kit. We do not have cold fusion kits because of politics, infighting, paranoid secrecy and the inventor's disease. Unforeseen technical problems have cropped up, but they would have been solved years ago with funding, and we would have gotten funding if the cold fusion scientists had acted rationally. Billions of dollars would have flooded into the field if the cold fusion scientists had demonstrated cells and freely published data on the Internet and in this and other magazines, instead of hiding their results. Politics, self-destructive behavior, and academic myopia are also holding back photovoltaics. Robert Huggins wrote:[21]

As is often the case in technological areas, the international photovoltaic research community has been charging off in a different direction from the commercial community. The [photovoltaic researchers] think that the important thing to do is to increase the efficiency, with no concern about price or safety. A typical example is the rush toward copper-indium-selenide and similar expensive and dangerous materials. Anything to get another percent or two in small laboratory samples.

In contradistinction, the real issue is power output per unit price.

Politics are a problem, but I conclude that genuine technical and commercial difficulties and competition from conventional sources of energy are hurting photovoltaics more than the kind of self-inflicted wounds that have stopped cold fusion. Photovoltaic cells have many commercial advantages over other

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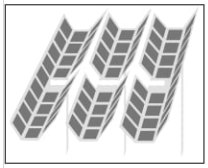
renewables, and over conventional energy in some applications. Their failure to achieve a significant market share is a valuable warning for cold fusion researchers. It is puzzling and disturbing. Photovoltaic cells seemed to have the perfect combination of attributes, described by Flavin and Lenssen:

- An established, lucrative niche market as power supplies for calculators, a 4-megawatt per year market.
- A growing presence in larger energy applications like roadside emergency telephones, telephone repeaters, transmission tower beacons, plant warning sirens, electric gate openers, cathodic protection for tanks and pipelines, remote metering systems and so on. Fifty thousand vacation homes in Norway have photovoltaic electricity and the number is increasing by around 8,000 per year.
- Many different potential manufacturing techniques, including radically new ones like the amorphous photovoltaic cells invented by Ovshinsky, with 10.2% efficiency.
- Rapid decrease in price. From 1975 to 1987 the cost per watt declined from $70 to $5. Unfortunately it has not declined much since then. It fell to around $4.20 in 1994.
- Rapid increase in sales. From 1970 to 1979 annual shipments increased slowly from near zero to ~2 MW, then increased rapidly to 60 MW in 1993.

Here are some advantages Flavin and Lenssen did not discuss:

- Fierce competition, and intense R&D by many different companies, including large established ones like Siemens, and aggressive start-up companies.
- Broad applicability, useful at any scale.
- Photovoltaic output is thermodynamically high grade energy, which can be used for any application. Most solar energy devices produce low grade heat suitable for space or water heating only.
- There are millions of roofs in the world in places like Los Vegas and Los Angeles which are exposed to bright sunlight nearly year round. In these locations, extra power for air conditioners is needed when the sun shines brightest, so solar-generated electricity is ideal. Photovoltaic panels can be mounted on roofs more easily than solar water heaters because they are lighter and they do not require plumbing, pumps or large holes in the roof or walls.



Despite these advantages, photovoltaics have not penetrated the broad energy market. Photovoltaic production is increasing, as shown in this table of world production: [22]

	1992	1993	1994	1995
Peak megawatts:	58	51	71	85
Percent increase:	8%	5%	16%	20%

The Worldwatch web site says 1997 production reached 125 peak megawatts.

Peak megawatts means the maximum power that would be derived from the total annual production of cells when every cell is exposed to optimum light. Actual average power is much lower because cells produce no electricity at night, and only a little on cloudy days. On average, you get about four hours of peak power per day in sunny locations. Cells are supposed to last as long as 20 years,[23] degrading no more than 10% in the first ten years, but actual performance is nowhere near this good. Thomas and Post found that cells at one installation degraded 70% in seven years.[24,25] Take the optimistic lifetime of 20 years and assume average output is equivalent to four peak hours per day. At the 1997 manufacturing rate, worldwide photovoltaic power output will expand to 417 megawatts. After that, all new cells will be needed to replace worn out panels. Four hundred seventeen megawatts is an insignificant fraction of world capacity, roughly equivalent to 0.01% of electric generator capacity.[26] Manufacturing will have to grow by thousands of percent per year before photovoltaics begin to make a significant impact on the energy market.

From the Worldwatch Web Site: www.worldwatch.org:

Worldwatch is a nonprofit public policy research organization dedicated to informing policymakers and the public about emerging global problems and trends and the complex links between the world economy and its environmental support systems...

The Worldwatch Institute is dedicated to fostering the evolution of an environmentally sustainable society—one in which human needs are met in ways that do not threaten the health of the natural environment or the prospects of future generations. The Institute seeks to achieve this goal through the conduct of inter-disciplinary non-partisan research on emerging global environmental issues, the results of which are widely disseminated throughout the world.

Prices must fall. Other alternatives, like wind power, have fallen in price faster and increased in reliability to the point where in some locations, wind is cheaper than fossil fuel and its use is increasing exponentially. In 1990, Weinberg and Williams listed bulk power electricity cost of various alternatives: [27]

Coal Base Load Power	4.5 cents per kilowatt-hour (KWH)
Wind	5 cents per KWH
Biomass	5 cents per KWH
Solar-thermal	11.5 cents per KWH
Photovoltaic projected	19 cents per KWH

That is a projected cost for photovoltaics; there are no actual bulk baseline figures because nobody would build a power plant that costs four times more than the competition. Photovoltaics had a long way to go in 1990 . . . Weinberg and Williams predicted photovoltaic costs of about 7 cents per KWH today (1998) and they predicted photovoltaics will be cheaper than coal by 2005. That was based on a straight line, unchanged cost of coal base-load power, which I find unrealistic. I predict that coal, oil and natural gas will be cheaper in 2005 than they were in 1990 thanks to improvements in prospecting and extraction.

It turned out that Weinberg & Williams were wildly over-optimistic. They predicted 12 cents per KWH in 1995. The American Solar Energy Society, which promotes photovoltaics, quotes NREL, a DoE laboratory: [28]

> An NREL study, "The True Cost of Renewables," indicates that the cost of electricity generated by utility-scale photovoltaic systems was approximately $0.218 per kilowatt-hour in 1995. The report also forecasts that costs will drop to $0.164 in the year 2000, to $0.131 in 2005, and to $0.087 in 2010.

There is no way electricity costing 16.4 cents will sell in the U.S. in the year 2000. That is two or three times more than electricity costs today. Weinberg & Williams estimated that photovoltaic baseload costs had already crossed this line three years before they wrote the article, in 1987. In fairness, they were estimating cost, not measuring it, as they made clear in the graph. (Other alternative energy costs were measured from actual pilot plants.) It is gratifying to learn that cold fusion advocates and hot fusion tokamak scientists are not the only ones who make embarrassing predictions. The American Solar Energy Society describes some of the prosaic problems that have kept photovoltaic (PV) costs high:

> The supply and price of silicon . . . Often silicon is not pure enough or unnecessarily pure and expensive – as it

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must be for semiconductors. Manufacturers are being forced to be more creative with the type of material and sizes they can use. Several PV manufacturers are working towards a unified silicon purchase agreement that would enable a company to supply silicon for PV's exclusively.

Manufacturing techniques are another cost cutting avenue. Wire saws that cut silicon crystal columns into individual wafers can reduce kerf losses (sawdust from wafer slicing) over circular saw methods . . .

In 1995 Flavin and Lenssen and many others hoped that mass production would radically lower photovoltaic costs. This has not happened, and some experts now question whether it ever will. Statistics on the Worldwatch web site show that the cost per watt has hardly changed in the last eleven years. It actually increased slightly from 1987 to 1990, and then fell back. Furthermore, about a third of the cost of a photovoltaic installation is for peripheral equipment like batteries and inverters – devices which have been mass produced and widely used in conventional energy applications for over a century.

In 1997 the Clinton Administration launched an initiative to install photovoltaics on "a million roofs" by the year 2010.[29] People who sell solar energy equipment for a living think this project is foolish. WindSun is a large retail vendor of solar generating equipment. Their web site features a biting essay designed to discourage customers who have fantasies of selling excess power to the electric company. They say: [30]

If you currently have electric power from your friendly utility, and think that solar electric is a way to save you money, or if you think that you can make money by selling power back, PLEASE!! Read This First before you call us . . .

Recently, there has been a lot of publicity about renewable energy, especially solar power. In our opinion, such things as 'A million solar roofs' etc. have done more to muddy the issue and raise false hopes than they have helped. None of these seem to present the down side or the economic issues.

WindSun says that in urban and suburban areas served by the grid, a photovoltaic installation would never pay for itself. Even if the photovoltaic chips cost nothing, the installation would not pay because the energy density is low, intermittent, and the inverters and other peripheral equipment is expensive, unwieldy, of limited lifetime, and subject to lighting damage and other environmental hazards. EPRI found that inverters incur the highest maintenance cost, and that overall maintenance costs for photovoltaic installations are 0.4 to 7 cents per kilowatt hour.[31] In most places, you cannot generate enough energy on your roof at home to make it worthwhile. The roof of an isolated shopping mall in Nevada might be a different story, but in the east coast of the U.S. solar energy is a losing proposition. WindSun looks at a typical installation and demonstrates that: "By spending $37,500 on solar panels, you have managed to increase your total payment per month from $200 to $302." Actually, they say the final cost would probably be more like $313 per month. I think it is unlikely that low energy density solar power will ever be of use in urban areas. Tying solar power to the grid is like augmenting a Mack truck engine with bicycle pedaling gear. Solar is marvelous for some applications. The people at WindSun conclude:

Off grid (remote power) has a totally different set of economics because you then have to consider that power lines can cost up to $75,000 a mile to run, and using a diesel or gas powered generator can get pretty expensive in the long term.

In a July 1998 press release, the Worldwatch Institute announced that photovoltaic cell sales increased 40% in 1997, to roughly 125 megawatts peak-watts. They say the average growth rate has been 16% per year since 1990. They claim that "roughly 800 megawatts of solar power capacity is now in place," but this still "represents less than 1 percent of global power supplies." It is far less than 1%, because these are peak watts in full sunlight. Even at that, I do not think installed capacity could have reached 800 peak megawatts. Worldwatch appears to assume that nearly every cell sold in the last 13 years is still installed and still working at the manufacturer's ideal rated warranty capacity. I estimated the annual production shown in the Worldwatch graphs since 1985, when production reached 20 megawatts and started to climb significantly. With an optimistic 1% per annum degradation rate I compute the installed base would be ~820 megawatts. However, Thomas and Post make it clear that cells do not work at rated capacity, they seldom meet warranty claims, and after ten years most of them produce such low power they would not be worth maintaining, or equipping with new batteries. With a degradation rate of 3%, which is still optimistic, and failure after ten years, the installed base would be ~700 peak megawatts. Given the difficulties at pilot installations reported in the literature, it seems unlikely that all ~700 peak megawatts are still installed, but even if they were they would produce roughly 117 megawatts average (at 4 peak hours per day), which is the size of one conventional power plant, or roughly 0.004% of worldwide electric generating capacity.

Two other issues that alternative energy advocates have not considered are the solid waste generated by the mountains of scrapped equipment, and energy overhead. These are related. Advocates often say that windmills and photovoltaic devices are made of recyclable materials. Silicon may be recyclable, but judging by a cross section diagram I think most of the mass of a photovoltaic chip is plastic packaging material, a notorious solid waste problem. "Energy overhead" refers to the amount of energy it takes to build, maintain, and finally scrap the energy generating equipment. Solarex Corporation estimated the energy required to manufacture a cell at 2.5 KWH per watt of output.[32] "A Solarex module in a sunny place . . . will in its life supply 20 times the energy it took to make it." In other words, energy overhead is roughly 5%. Solarex does not attempt to measure the "embedded energy" in the silicon, because that would be complicated and the silicon is semiconductor scrap which would have been thrown away if Solarex had not used it. I expect present manufacturing facilities are low volume pilot plants, so efficiency is low. A larger factory would do better than 20:1. The embedded energy in silicon is probably low, because the devices use little silicon. Four or five percent is probably a fair number.

This 5% overhead sounds dismal, but actually it is better than conventional energy systems. In 1985 worldwide crude oil production was 59 million barrels per day. Four million barrels, or 7%, were cycled back into the system in "Refinery Use / Loss."[33] Natural gas production was equivalent to 29 million barrels of oil. Of this, 3 million or 10% was wasted in "Transmission Loss." Eight percent of centrally generated electricity is lost in transmission. Very little photovoltaic electricity will be wasted if it is consumed on site. On the other hand, this 5% overhead may be a gross underestimate, because it does not include the cost of transporting, assembling, maintaining, and finally scrapping, recycling or burying worn-out photovoltaic chips, plus the additional overhead from peripheral devices like batteries and inverters. The overall cycle might be close to zero-

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using perhaps a third as much fossil fuel as it saves. The overead issue has not been adequately addressed in the books, articles and web sites I reviewed for this article.

Lessons for Cold Fusion

The good news is that cold fusion will have significant practical advantages over energy sources like photovoltaics and windmills:

•Cold fusion power can be supplied at any power level, uninterrupted, at any hour of day, in any weather. Alternatives like solar and wind are intermittent and unpredictable. Maximum output is limited by the size of the roof or the number of windmills. Solar never works at night and it works poorly in winter. Small hydroelectric installations do not work well during droughts. These systems must be connected to the power grid or supplemented with conventional gas or diesel power, or energy storage (batteries) which makes them twice as complicated, expensive and trouble prone. They have the disadvantages of both distributed *and* locally generated power. Cold fusion will stand alone without a supplement or requirement for energy storage.

•Cold fusion co-generators will be installed indoors, where furnace and air conditioners are located. They will not be exposed to hazards like lightning and rain.

•Cold fusion does not require expensive materials. It will be smaller and lighter than a photovoltaic array, and probably cheaper. It will be particularly cost effective when used as a co-generator water and space heater.

•Because cold fusion energy density is high, a cold fusion generator will be more compact than solar, wind, or a small hydroelectric installation. It will take less landfill space when it is scrapped. It will not require an ugly infrastructure of towers.

•Windmills and polished mirror-like solar collectors kill birds; hydroelectric dams ruin streams. Cold fusion generators will have no deleterious effect on the environment.

•Cold fusion has all of the advantages of renewable energy versus fossil fuel: it is clean and requires virtually no fuel. It has other, unique advantages over both systems. For example, as Arthur Clarke pointed out, when cold fusion becomes the standard, home electric power systems might be direct current at low voltage, to avoid the danger of electrocution, and eliminate the need for an inverter.[34] You could do this with photovoltaic systems, and companies like WindSun sell special, direct current, low powered lights and other equipment. When cold fusion becomes popular, the market for this may boom, making it the standard. Either that, or power supplies will be miniaturized and built into stoves, dishwashers, portable computers, talking dolls, and so on, eliminating wires and outlets.

•Cold fusion will eliminate the energy overhead problem. Whether we devote 5% of our energy to make cold fusion machines or 50% we will not care, because the cost of the overhead energy will be zero either way. In fact, I do not anticipate that it will take more than a few percent overhead, less than conventional or alternative energy sources.

The bad news is that promising energy technologies are a tough sell. People who think that cold fusion will be easy to implement should read this book carefully, and spend some time slogging through a few hundred pages of tomes like *Renewable Energy*. The prospects are grim. Before we can attract funding, we must overcome a seemingly impossible barrier: we must build and demonstrate a prototype reactor. Most cold fusion scientists are retired professors. At the present rate of progress they will die before they achieve any practical goals. Most of them express no interest in building a demonstration device even if they were able. Most of them alienate potential investors with outrageous demands and paranoid secrecy. The technical problems confronted by cold fusion researchers are daunting. They cannot be solved by isolated groups of scientists puttering away in their basements in secrecy, any more than the Wright brothers could have built a Douglas DC-1 airplane in their bicycle shop. The problems are large, but no larger than those faced in aerospace, electronics, telecommunications, and countless other fields of commercial technology. There is no reason to believe these problems cannot be solved with money and good management. A few cold fusion scientists, like Storms and Mizuno, have made enormous progress working on a shoestring. Just imagine what a thousand people of this caliber could do with proper funding!

Even if cold fusion demonstration reactors worked today, many technical and economic impediments would remain, as *Power Surge* and other books on alternative energy make clear. Cold fusion must be made reliable, it must be certifiably safe, and it must be competitive. Cold fusion fuel costs nothing, but you can say the same for photovoltaic cells, yet they cost much more per kilowatt hour than fossil fuel generators.

We must first overcome the resistance of the cold fusion scientists, who seem determined to prevent the development of this technology. Then we must perfect the machines and make them commercially competitive. Then, unfortunately, we face a larger hurdle that solar and wind alternative energy has not faced: hysterical opposition from the establishment and vested interests. This has already stymied cold fusion research by frightening away young scientists and drying up funding. The opposition will grow immeasurably stronger when people realize cold fusion is real. Flavin and Lenssen describe the deep-seated ignorance and rear view mirror vision of mainstream energy organizations like the World Energy Council and the DoE, who are bound to oppose cold fusion to the bitter end. Flavin and Lenssen are apparently indifferent to cold fusion, and their hero Lovins despises it.[35] Both sides oppose us. We have no allies and no prospects for gaining any, either in the establishment or the anti-establishment environmentalists and anti-nuclear groups.

There are only two groups who can rescue us: investors and consumers. If we can manage to build and demonstrate a device, no matter how impractical it might appear at first glance, the investors will come running. And if we begin selling generators for high cost niche markets, the consumers will come – because they are not fools, and they have no policies or agendas except their own best interests. Opinion makers like *Scientific American* or *Nature* magazine cannot break a consumer's career. The energy companies will howl, the lobbyists will put pressure on Congress to ban cold fusion or tax it to death, but in the end, the voters and consumers have the power to push aside these vested interests, and history has shown they will do it. Voters in the U.S. are apathetic until an important issue comes along. They will see that cold fusion is important, and they will take action. The cold fusion scientists and development companies must take the first step. Then, market forces will swing into action and ensure success. The triumph will not be inevitable until individuals act, and set in motion larger forces, the way a person triggers an avalanche by tossing a snowball. Inventions like the automobile and the personal computer may seem in retrospect to be unstoppable and inevitable, but they were held back for years by lack of interest and by a failure of imagination. Nobody bothered to bring them to the market. Believe it or not, many people doubt that cold fusion will have a market, or that it is worth pursuing. The technical ability to achieve a goal is not enough; someone must have the

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will to do it, the desire, the sense that it is worth the trouble. The inventor Hiram Maxim wrote: [36]

It has been the habit to give the gasoline engine all the credit for bringing in the automobile—in my opinion this is the wrong explanation. We have had the steam engine for over a century. We could have built steam vehicles in 1880, or indeed in 1870. But we did not. We waited until 1895.

The reason why we did not build road vehicles before this, in my opinion, was because the bicycle had not yet come in numbers and had not directed men's minds to the possibilities of long distance travel over the ordinary highway. We thought the railroad was good enough. The bicycle created a new demand which went beyond the ability of the railroad to supply. Then it came about that the bicycle could not satisfy the demand it had created. A mechanically propelled vehicle was wanted instead of a foot propelled one, and we know now that the automobile was the answer.

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O'Donnell continued from page 57

of each steel rod. The attractive force from the magnet to the rod gives a further impulse to the display wheel. Once magnets start to cross the display wheel just behind each steel rod, you are then slowing the display wheel. This is what I call getting out of synch.

The problem with my setup is that the display wheel is too light. The impulse from a single magnet can speed up the display wheel with a quick increase in rotation speed. This sudden increase in speed makes it harder to adjust the rotation of the drive wheel, but with practice it is possible to rotate the display wheel for some minutes. Eventually, you always get out of synch, but you can usually correct the problem, while the display wheel is still turning, by making an adjustment in drive wheel speed, after which you will eventually get out of synch again, and restart the process all over.

What makes rotating the display wheel through attractive force coupling to the drive wheel is a human controlling the drive wheel. Maybe with a heavier display wheel you can reach a speed which you can maintain by a steady rotation speed of the drive wheel. This constant speed would then be maintained by the drive wheel slowly slipping in and out of synch with the display wheel. This initial try is too light to determine that.

I will send Cold Fusion Technology, Inc. both wheels, complete with extra magnets and extra rubber bands, so a verification of my initial conclusions can be made. The wheel shafts are standard 5/8" by three feet round stock sold by any hardware store for about $1.70 each.

What I am planning next in this experiment is constructing a three foot display wheel. On this wheel I will have most of the parts machined for me by a machine shop. I will do it, like I imagine Bessler would have done it. The steel or iron portions of the display wheel will be capable of complete disassembly for easy knockdown and transport to the next town on the tour. The iron or steel portions will be simple enough for any gunsmith in 1712 to fabricate, with the help of a blacksmith.

However, in the interim, I have to take a break. I will let you know how the three foot wheel is progressing. If it works out, let's build a 12-foot model, and then try to push it off as a perpetual motion machine. I'll sell it to Collins real cheap, but he has to pay for it in cash on the day he accepts delivery.

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The author, Frank Znidarsic, has a B.S. in Electrical Engineering from the University of Pittsburgh, has an Associate in Science from Saint Francis College, and is a registered professional engineer in the state of Pennsylvania.

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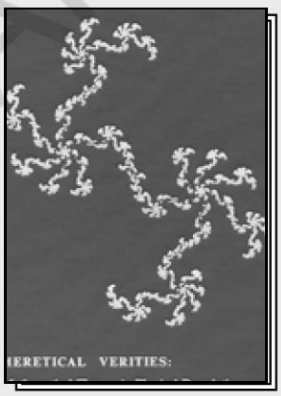

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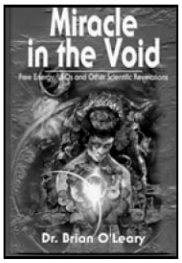

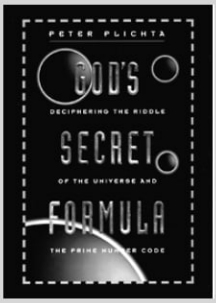

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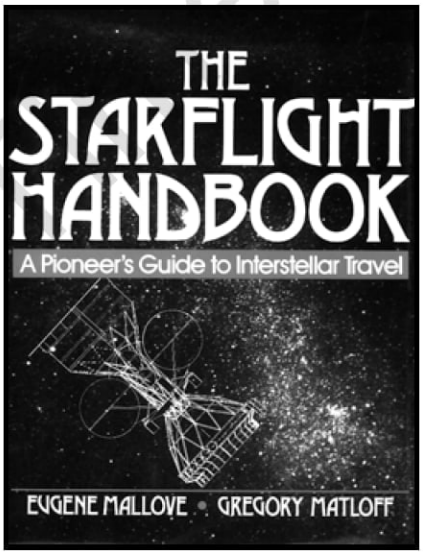

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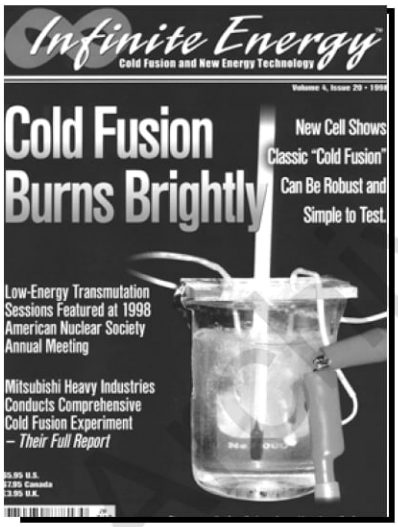

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